NOAA Technical Memorandum NMFS-SEFSC-574

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Photo credit: Sarah Wilkin

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NOTICE

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EXECUTIVE SUMMARY

Ten rough-toothed dolphins (*Steno bredanensis*) that mass-stranded in the Florida Keys in March 2005 were rehabilitated, tagged, and released in three different efforts, during April, May, and September, 2005. Along with an untagged dolphin, one of the dolphins was tagged and released by the Marine Animal Rescue Society (MARS) in Miami, Florida on 20 April 2005. Nine other dolphins were tagged and released by the Marine Mammal Conservancy (MMC), Key Largo, Florida. Seven of these were released on 3 May 2005, and two more were released on 12 September, 2005. Small VHF transmitters were attached for direct radio-tracking to all nine of the dolphins released by MMC. Five dolphins were tagged with satellite-linked transmitters, four of these were tags that provided dive data in addition to locations.

Satellite-linked transmitters proved to be the most effective means for performing follow-up monitoring of the dolphins. The VHF transmitters were of use in only one case, when the May dolphins were tracked from a helicopter to the shallow waters off the western coast of Andros Island. The five dolphins tagged with satellite-linked transmitters were tracked over periods ranging from 12 to 49 days, traveled 687 to 3,488 km over the durations of the five tracks, and averaged 55-99 km/day. There was no consistency to the tracks of the tagged dolphins across the three release events. The dolphin released in April initially moved north offshore as far as Charleston, SC, then moved south alongshore to the Florida Keys, before once again turning north, with final signals off Miami, FL. When releases involved multiple tagged dolphins, the individuals within a release appeared to remain together through much if not all of the tracks. The dolphins released in May appeared to remain together as they moved east from the Florida Keys to the shallow waters west of Andros Island in the Bahamas, then along the southern part of the Great Bahama Banks, followed by a northward turn at Columbus Bank leading through Crooked Island Passage. A northerly track for several days along the 5,000 m contour led to a turn to the southeast that continued until signals were lost northeast of Antigua. The September release involved movements by both dolphins southward from the Florida Keys through the Santaren Channel and Old Bahama Channel to the coastal waters off Cayo Coco and Cayo Fragoso in northern Cuba, where signals were lost a few days after the passage of Hurricane Rita. Dives were typically to less than 100 m, for durations of less than four minutes.

In the absence of strong, direct evidence to the contrary, these three releases of ten tagged dolphins should be considered as qualified successes. Three of the dolphins were documented as having survived more than four weeks. In spite of the fact that the final contacts with eight of the 10 dolphins were near shore, no carcasses were reported or recovered. Abrupt loss of radio contact with each of the dolphins with satellite-linked transmitters was believed to be related to tag attachment failure, possibly as a result of allogrooming by the dolphins.

The results of this project support the idea that every effort should be made to release animals from mass strandings together, and in appropriate habitat near the stranding site. Findings suggest that releasing members of the stranded school in three separate instances disrupted whatever school integrity might have remained at the time of stranding, beyond the changes from the deaths of school members. The May animals clearly demonstrated disorientation shortly after release. While they may have survived the stranding and the rehabilitation process, the lives of the animals in decimated subgroups was likely very different from what they had experienced prior to stranding, and long-term survival and school functionality can not be assumed.

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INTRODUCTION

Follow-up monitoring of released, rehabilitated dolphins such as the rough-toothed dolphins (*Steno bredanensis*) of the March 2005 mass stranding in the Florida Keys, has the potential to be an opportunity to evaluate the success of treatments during rehabilitation, as well as providing opportunities to learn about the biology of species that are otherwise difficult to study in the wild. Rough-toothed dolphins (hereinafter referred to as "stenos") are widely distributed through the world's tropical and warm temperate seas, but they tend to be pelagic, deep-water animals, found far from most shores including Florida (Leatherwood and Reeves 1983; Miyazaki and Perrin 1994), and are therefore not well-studied by biologists. The pelagic nature of the species suggested that follow-up monitoring of rehabilitated stenos was likely to require an approach that would permit continued contact with the animals even when they moved beyond the range of shore-based small boats and aircraft. We selected an approach of a combination of VHF and satellite-linked transmitters for most of the animals, which allowed for the possibility of direct tracking and observation of the animals should they remain or come near shore, as well as providing a capability for obtaining data remotely on movement and dive patterns, should the dolphins move too far offshore for direct observations.

Ten of the stenos that mass-stranded in the Florida Keys in March 2005 were rehabilitated, tagged, and released in three different efforts, during April, May, and September, 2005. One of the dolphins, SbRTY366 "Notch," was tagged and released by the Marine Animal Rescue Society (MARS) in Miami, Florida on 20 April 2005. Notch was released with an untagged female steno ("Naia" SbRTY363/Y364). Follow-up monitoring was performed by Greg Early. Nine other dolphins were tagged and released by the Marine Mammal Conservancy (MMC), Key Largo, Florida. Seven of these were released on 3 May 2005, and two more were released on 12 September, 2005. The MMC dolphins were tagged and tracked by Randall Wells.

MATERIALS AND METHODS

The dolphins were tagged with a variety of transmitters for follow-up monitoring, including small VHF transmitters for direct, real-time tracking, should the dolphins come within range of our short-range tracking capabilities, and satellite-linked transmitters for remote, long-range tracking and data collection, for the period when direct tracking was not logistically feasible. All of the transmitter designs deployed with the stenos have been used with success previously for research and follow-up monitoring of released rehabilitated cetaceans.

Short-range Tracking

Small VHF transmitters were attached for direct radio-tracking to all nine of the dolphins released by MMC (Table 1). Each 13.5 g transmitter (Advanced Telemetry Systems, Inc., Isanti, MN; Model#: MM130; Pulse Rate: 100 ppm; Pulse Width: 25 ms; 35 cm antenna angled upward) was configured for attachment in a plastic "bullet" tag holder (Trac Pac, Inc., Ft. Walton Beach, FL), and attached to the trailing edge of the dorsal fin by a single 64 mm diameter delrin pin with two corrosible lock nuts (Figure 1). Warranty battery life for this light-weight transmitter was 50 days, though past experience has demonstrated performance significantly in excess of specifications (battery capacity is 101 days). Tracking range for this transmitter varied with tracking antenna height above the water and sea state, from a few kilometers during tracking from a small vessel to more than 10 km from an aircraft.

Table 1. Tags deployed and tagging results.

DOLPHIN	SEX	PTT	TAG	VHF FREQ (MHz)	TAG DATE	DEPLOY LOCATION	LAST SIGNAL	# DAYS
SbRTY366	Male	39381	Spot4	na	20 Apr	Atlantic - off Miami	07 Jun	49
SbRTR307	Female	54612	Splash, VHF	148.686	03 May	Atlantic - off Florida Keys	01 Jun	30
SbRTY352	Male	57604	Splash, VHF	148.587	03 May	Atlantic - off Florida Keys	09 Jun	38
SbRTY354/Y372	Male	na	VHF	148.407	03 May	Atlantic - off Florida Keys	na	na
SbRTR136	Female	na	VHF	148.507	03 May	Atlantic - off Florida Keys	na	na
SbRTR354	Female	na	VHF	148.627	03 May	Atlantic - off Florida Keys	na	na
SbRTR306	Female	na	VHF	148.806	03 May	Atlantic - off Florida Keys	na	na
SbRTR304	Female	na	VHF	148.837	03 May	Atlantic - off Florida Keys	na	na
SbRTR134	Female	42480	Splash, VHF	148.506	12 Sep	Atlantic - off Florida Keys	23 Sep	12
SbRTR372	Female	42481	Splash, VHF	148.807	12 Sep	Atlantic - off Florida Keys	25 Sep	14

Figure 1. Dolphin SbRTR372 (PTT 42481), with VHF "bullet tag" attached to the trailing edge of the fin by a single pin, and satellite-linked transmitter attached by 3 similar pins.

Long-range Tracking

Five dolphins were tagged with satellite-linked transmitters (Table 1). Two different satellite-linked transmitters were used, both produced by Wildlife Computers, Inc. (Redmond, WA). One of the dolphins (SbRTY366 "Notch" – released by MARS) was fitted with a Spot4 transmitter that provided location data. The tag was configured with a single M1 battery, with an estimated life of 15,000 transmissions. The other four dolphins (released by MMC) were fitted with Splash tags (Figure 1). Splash tags are satellite-linked time-depth recorders consisting of a satellite transmitter (PTT: Cricket), controller board, pressure transducer, and battery cast in epoxy and designed for water depths of up to 1,000 m (8.0 cm L x 4.5 cm H x 2.2 cm W, 70 g; 20-cm semirigid antenna). The Splash tags were each powered by a single AA battery, generating 0.5 W of radiated power, with estimated battery life of 25,000 transmissions.

Both of these kinds of satellite-linked transmitters, with closed-cell foam backing, were attached as side-mounts to dorsal fins by three 64 mm delrin pins, secured on the opposite side of the fins with padded washers and corrosible nuts (Figure 1). The tag size and configuration were selected to minimize coverage of the thermoregulatory surfaces of the fin, minimize the number of holes that needed to be made through the fin, and optimize the ability of the animal to shed the tag with minimal risk of injury should it become entangled in line or net.

The Spot4 tag was programmed to transmit during two six-hour blocks each day (GMT 1100-1559 and 2000-0159), with a maximum of 400 transmissions per day.

The two Splash tags deployed in May were programmed to transmit around the clock for the first day, and during two four-hour blocks each day (GMT 0900-1359 and 2000-0059) thereafter. For June, the transmission schedule switched to every other day in order to reduce battery drain. The daily transmit allowance was 500 transmissions, meaning that the maximum number of expected days of transmission was 50. The tags were programmed with 14 data bins established for each parameter (with histograms collected as SDR-T16 formatted data). Programming allowed for measurement of dives to greater than 700 m (up to 1,000 m), and for dive durations of more than 420 seconds. Dives were defined initially as excursions below the surface in excess of 1 m (a dive was subsequently defined for analyses as any submergence greater than 2 m to better differentiate between actual dives and time spent at the surface, and for consistency with data collected in September). The tags were programmed to record ambient temperature readings within a range of -2^o to more than 33^{o}C.

The two Splash tags deployed in September were programmed to transmit around the clock for the first day, and during a single eight-hour block each day (GMT 1300-2059) thereafter. The daily transmit allowance was 250 transmissions, meaning that the maximum number of expected days of transmission was 100. The tags were programmed with 14 data bins established for each parameter (with histograms collected as SDR-T16 formatted data). Programming allowed for measurement of dives to greater than 700 m (up to 1,000 m), and for dive durations of more than 420 seconds. A dive was defined as any submergence greater than 2 m to differentiate between actual dives and time spent at the surface. The tag was programmed to record ambient temperature readings within a range of -2^o to more than 33^{o}C.

Data were transmitted from the tags with a 45 s repetition rate to the Argos satellite system (Service Argos, Inc., Landover, Maryland, USA). Satellite transmissions were processed by Service Argos. On-line queries provided data as soon as they became available from Argos (usually within several hours of tag transmission). Data summaries from Splash tags were sent by Argos to Mote Marine Laboratory's Center for Marine Mammal and Sea Turtle Research daily via e-mail, and monthly data summaries were provided on cd-rom. Data were distributed by the Center for Marine Mammal and Sea Turtle Research daily via e-mail to appropriate parties, including NMFS staff. Data were returned from Argos relative to GMT (UT), but times were converted to EDT (-4 hrs from UT) for some analyses. Position accuracy was designated to 6 location classes (LC). An LC 3 has an accuracy estimate of: ≤ 150 m, LC 2 ≤ 350 m, LC 1 ≤

1000 m, LC 0 > 1000 m. Location classes A and B require only two transmissions to provide a location with unknown quality and therefore do not give an accuracy estimate.

Locational data were examined using Argos_Filter V7.02 to filter all plausible locations (Douglas 2006, http://alaska.usgs.gov/science/biology/spatial/). The program identifies implausible locations based on two different filtering methods. The first is a minimum-redundant-distance (MRD), a user-defined distance utilized as a threshold for determining redundant locations. The second method is the distance, angle, and rate measurement (DAR) that attempts to remove implausible locations based on the fact that most suspicious ARGOS locations cause the animal to incorrectly move a substantial distance and then return with the subsequent location being more correct (Douglas 2006). A rate of 20 km/hr was used as the sustained rate of travel threshold to evaluate the plausibility of the locations. All positions with LC of 1 or greater were automatically included. The maximum redundant distance threshold was set at 15 km.

Three kinds of output are produced by this program, one for each of the filtering strategies and a third more-experimental output that pools selected DAR locations to the MDR results. This program also defines the best daily location per dolphin based on the pooled MDR and DAR outputs. From the filter output, distance traveled is calculated as the distance (km) from the previous plausible location and mean rate of travel is calculated as the rate of movement (km/hr) between two successive locations. These distances do not describe the actual distance traveled in a day, but rather the distances between successive points. The DAR filter was determined to provide the best results, based on percentage of plausible positions. The filter was used in two iterations. The first run removed points that were implausible based on the filter algorithm alone. The points remaining after this first run were plotted and inspected visually for plausibility (e.g., positions on land were not plausible). A few more points were removed, and filter was run again to make certain that the removals did not change the acceptability of remaining points. More than 90% of locations successfully passed the DAR filters for each dolphin (Table 2). The passing locations were used for subsequent analyses.

Table 2. Results of position data filtering, using the Distance-Angle-Rate filter.

DOLPHIN	NO. OF PASSING POSITIONS	% POSITIONS PASSING D-A-R FILTER
39381 SbRTY366	289	92.6
54612 SbRTR307	216	90.4
57604 SbRTY352	221	93.3
42480 SbRTR134	45	93.8
42481 SbRTR372	46	95.8

We examined position data relative to several environmental parameters. Filtered Argos positions were entered into a Geographic Information System (GIS) and overlaid with bathymetry, slope, and sea surface temperature layers to extract environmental data for each location. Bathymetry was obtained from the "ETOPO" global 2-minute resolution data set (Smith and Sandwell 1997, data available at http://www.ngdc.noaa.gov/mgg/image/2minrelief.html).

In addition to basic water depth, underwater physiographic features can influence movement patterns of dolphins. Interactions between currents and ridges and escarpments can lead to areas of increased productivity as nutrients are brought to the water's surface. We used slope as an indication of the animals' use of these features. Slope was derived from this bathymetry using ArcGIS Spatial Analyst by calculating the maximum rate of change in value from each cell to its neighbors.

Temperature was measured in two ways. The Splash tags transmitted temperatures recorded as histograms of time-at-temperature, presented as the number of records within specified temperature range bins. These were then converted to the proportion of time the animal spent within a specific temperature range. The tag temperature dataset integrates water temperatures through the water column, as it represents readings obtained through the dolphins' dive cycles. Sea surface temperature, where available, was obtained remotely from MODIS Aqua thermal-far infrared bands, at resolutions of 4 km and 8 day averages (data available at http://poet.jpl.nasa.gov/). To extract values for environmental variables at each location, the ArcGIS extension "Gridspot" was used.

Dive and tag temperature data were returned from Argos as histograms, presented as the number of occurrences within programmed "bin" categories within programmed six-hour time blocks. Converted to Eastern Daylight Savings Time (EDT), the blocks represent: Dawn: 0300-0859; Day: 0900-1459; Dusk: 1500-2059; Night: 2100-0259. Data within bins were analyzed as percentages of total occurrences. For dive depths, the bin for the first 2 m was excluded from analysis because of the "noise" introduced by including the large number of apparent submergences that were not true dives. Similarly, the bin for the first 30 sec of dive durations was excluded because these were likely often the result of repeated surfacings associated with respirations between true dives. A potentially very useful Splash tag feature that is supposed to indicate maximum daily dive depth did not function properly for these four tags.

RESULTS

Satellite-linked transmitters proved to be the most effective means for performing follow-up monitoring of the dolphins. The VHF transmitters were of use in only one case, when the seven dolphins released in May were tracked from a helicopter to the shallow waters off the western coast of Andros Island. The five dolphins tagged with satellite-linked transmitters were tracked over periods ranging from 12 to 49 days (Table 1). The dolphins traveled 687 to 3,488 km over the durations of the five tracks, and averaged 55-99 km/day. Overall, 45-289 plausible locations per dolphin accounted for 90-96% of all position estimates (Table 2).

The durations of transmitter lives varied from tag to tag (Table 3). Only one of the tags reached or exceeded the expected number of transmissions. Notch's (SbRTY366) Spot4 tag exceeded by 37% the estimated 15,000 transmissions expected for the M1 battery configuration of the tag. Battery voltage was declining steadily over the last few transmissions, but was still at an acceptable level at final transmission. The four Splash transmitters ceased transmitting well before achieving the expected 25,000 transmissions. In only one case (42481 SbRTR372) was final battery voltage below the value required for successful transmissions, suggesting possible premature battery failure (Table 3). In the remaining cases, the reasons for cessation of transmissions remain unclear, with failure of tag electronics, premature attachment release, or dolphin mortality as possibilities.

Table 3. Tag status associated with final signals.

DOLPHIN	AVERAGE BATTERY VOLTAGE, LAST 2 DAYS	CURRENT DRAW AT LAST TRANSMISSIONS	TOTAL # OF TRANSMISSIONS
39381 SbRTY366	3.16	na	20,480
54612 SbRTR307	3.16	0.28	13,824
57604 SbRTY352	3.06	0.21	15,104
42480 SbRTR134	3.31	0.25	4,096
42481 SbRTR372	2.92	0.24	4,352

General Movements

There was no consistency to the tracks of the tagged dolphins across the three release events; they resulted in three very different tracks for the sets of dolphins (Figures 2, 3, 4). Notch (SbRTY366), released in April, initially moved north offshore as far as Charleston, SC, then moved south alongshore to the Florida Keys, before once again turning north, with final signals off Miami, FL (Figure 2). For the two releases involving multiple tagged dolphins, the individuals within a release appeared to remain together through much if not all of the tracks. The dolphins released in May appeared to remain together as they moved east from the Florida Keys to the shallow waters west of Andros Island in the Bahamas, then along the southern part of the Great Bahama Banks, followed by a northward turn at Columbus Bank leading through Crooked Island Passage (Figure 3). A northerly track for several days along the 5,000 m contour led to a turn to the southeast that continued until signals were lost northeast of Antigua. The third release, in September, involved movements by both dolphins southward from the Florida Keys through the Santaren Channel and Old Bahama Channel to the coastal waters off Cayo Coco and Cayo Fragoso in northern Cuba, where signals were lost a few days after the passage of Hurricane Rita on 20 September (Figure 4).

Figure 2. Track of dolphin SbRTY366 **"Notch" during 20 April – 7 June, 2005. Only positions successfully passing the D-A-R filtering process are indicated. Bathymetry contours are indicated in meters.**

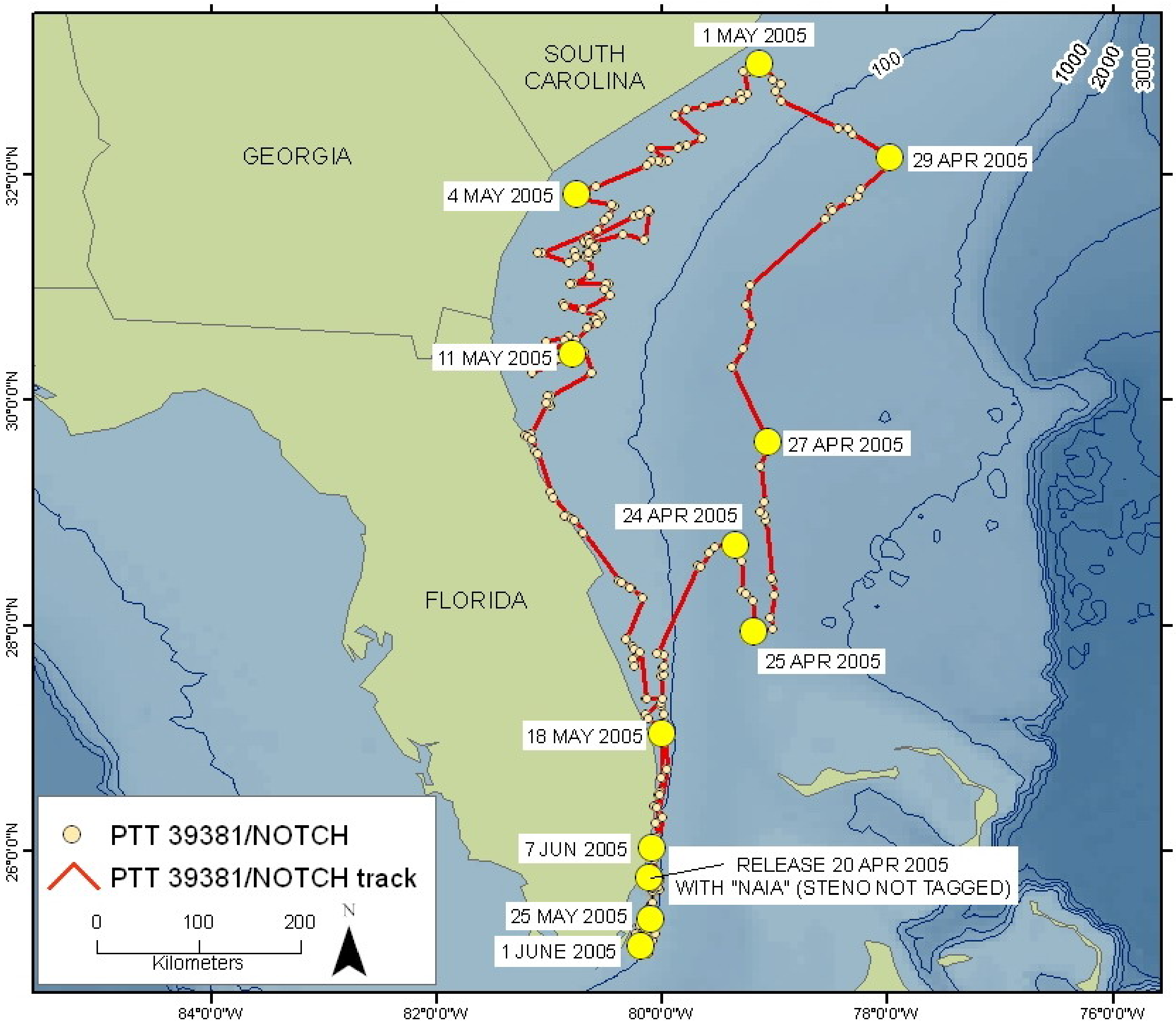


Figure 3. Tracks of dolphins 54612-SbRTR307 and 57604-SbRTY352, 3 May – 9 June, 2005. Only positions successfully passing the D-A-R filtering process are indicated. Bathymetry contours are indicated in meters.

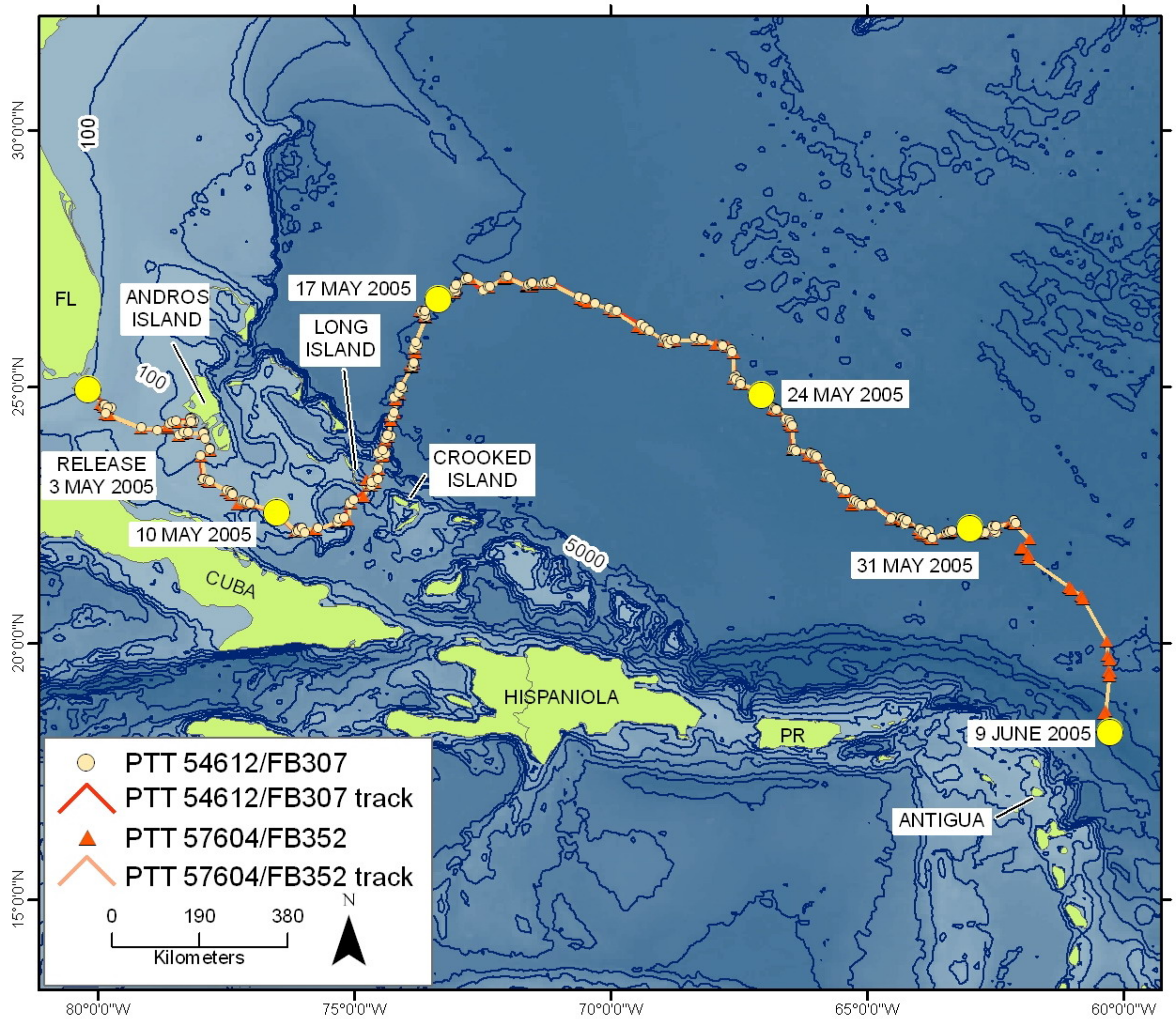
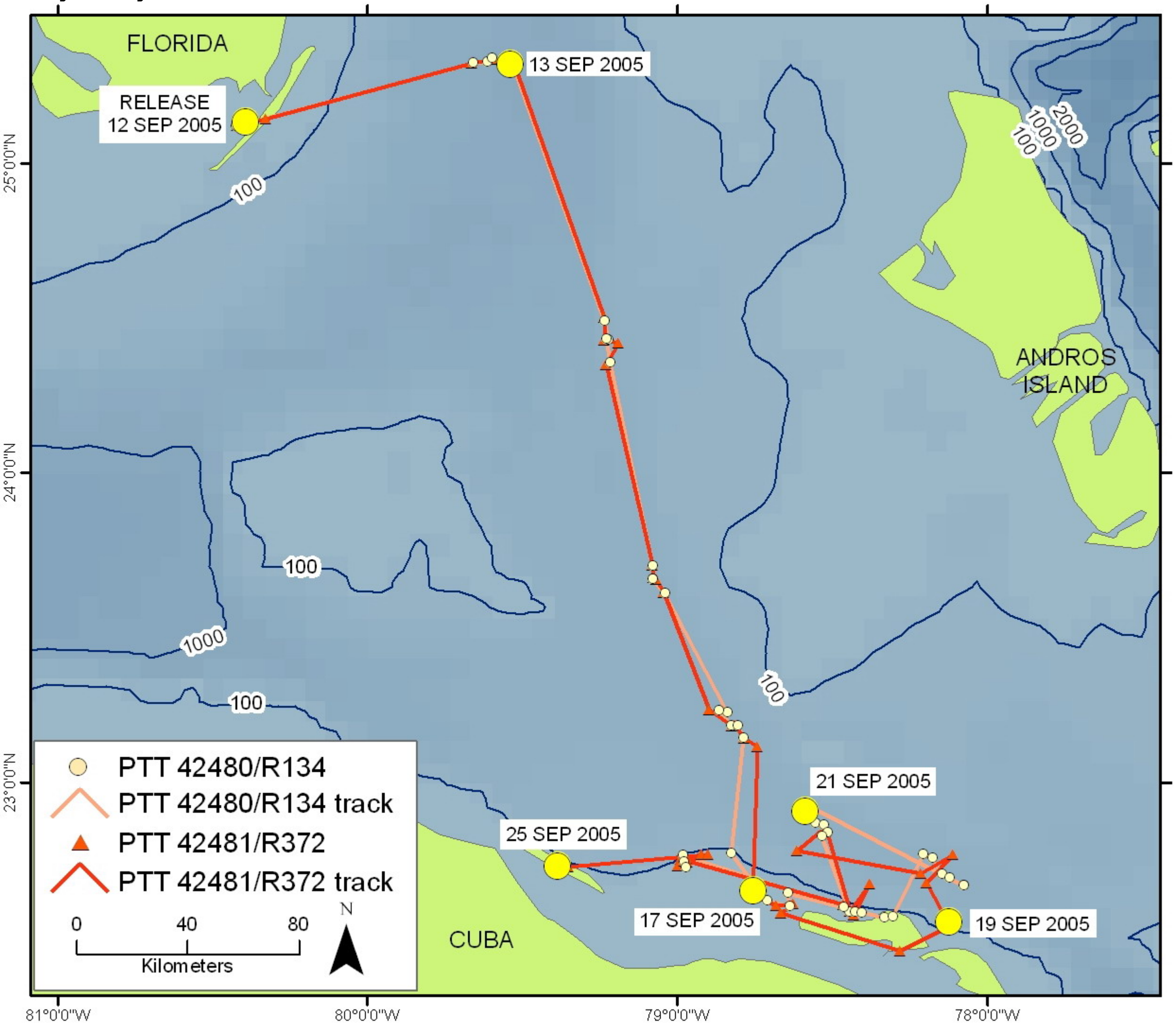


Figure 4. Tracks of dolphins 42480-SbRTR134 and 42481-SbRTR372, 12-25 September, 2005. Only positions successfully passing the D-A-R filtering process are indicated. Bathymetry contours are indicated in meters.



<u>Movements Relative to Environmental Parameters</u>

The movements of the dolphins carrying satellite-linked transmitters were examined relative to several environmental factors, including water depth (Table 4), the slope of the sea floor as an indication of nearness to escarpments (Table 5), and both tag and sea surface temperature (Tables 6, 7).

<u>*Water Depth*</u>

All five of the tagged dolphins moved through a large range of water depths, from very shallow (approximately 1 m) on rare occasions to very deep (up to 6,720 m). Overall averages for water depths were greater than 100 m, ranging from 122 m for Notch (SbRTY366) to 4,132 m for SbRTY352 (Table 4). There were no significant differences between averages calculated from the single best position for a given day *vs*. using all of the available filtered position data.

Median water depth for Notch was only 27 m, while the other four dolphins had values more than one or two orders of magnitude higher.

Table 4. Water depth (m) associated with positions of tagged dolphins.

DOLPHIN:	39381 SbRTY366	57604 SbRTY352	54612 SbRTR307	42480 SbRTR134	42481 SbRTR372
Mean	122	4,132	3,916	388	308
Median	30	5,323	5,159	489	262
Standard Dev.	233.8	1,991.9	2,302.8	275.3	271.1
n	280	220	214	41	42
Minimum	1	4	4	1	1
Maximum	864	6,720	5,853	855	873

Each of the five tagged dolphins moved through very shallow waters at some point during their tracks. Notch moved very close to the north Florida shoreline on his southward leg during the fourth week post-release, and subsequently moved very close to shore in south Florida and the Florida Keys as well (Figure 2). Stenos are not commonly seen along Florida's shallow coasts.

The dolphins released on 3 May moved southeast following release, to the very shallow waters just west of Andros Island in the Bahamas (Figure 3). They spent several days (5-8 May) milling in these shallows, and slowly working their way to the south tip of the island (Figure 5). Because of concerns from the lack of movement and the nearness to shore that these animals might have stranded on Andros Island, a helicopter was dispatched on 7 May to find them. Working from the most recent satellite position data, the dolphins were tracked successfully via VHF transmitter to a shallow sandbank near southern Andros Island. Photographs were obtained of the seven animals milling in close proximity to one another (Figure 6a), and oriented in different directions (Figure 6b). Once the dolphins moved away from Andros Island on 8 May, they remained in deeper water, with the exception of passing over Cochinos and Columbus Banks on 9-10 May. Once past these banks, they followed the deep water of Crooked Island Passage to the north of the Bahamas Island, and remained in waters several thousands of meters deep thereafter. Stenos are not commonly found in the shallow waters of the Bahamas.

Figure 5. Map showing positions of tagged dolphins over shallow sandbanks near Andros Island, Bahamas, 5-8 May 2005.

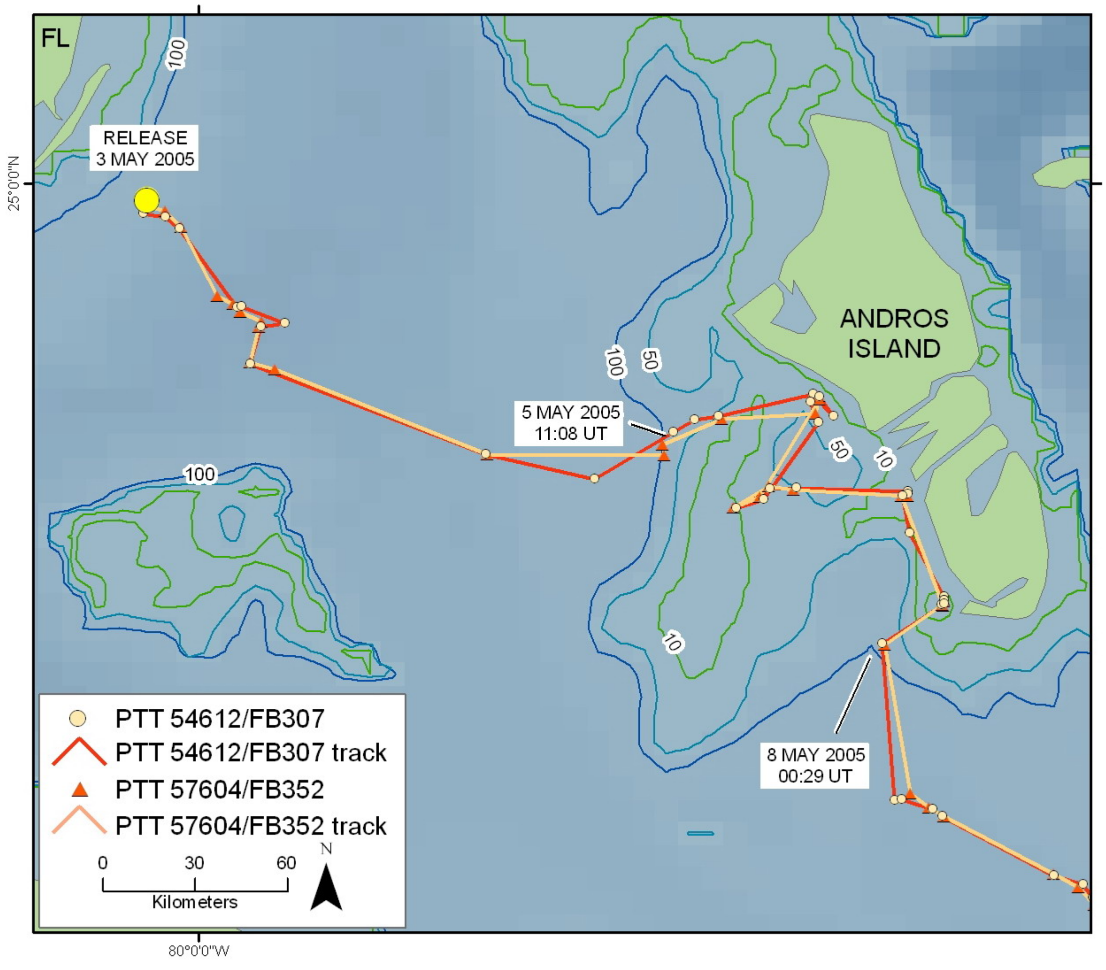


Figure 6a,b. Photos of tagged dolphins over shallow sandbanks near Andros Island, Bahamas, at 1430 hrs on 7 May, showing all seven dolphins still together, four days post-release. The dolphins were located at approximately 23^{o} 46' 07" N, 77^{o} 49' 25" W. Photos by Mark L. Lay.

6a.

6b.

The dolphins released on 12 September moved from the deep waters of the Florida Straits, southward through the Santaren Channel and Old Bahama Channel to the coastal waters off Cayo Coco and Cayo Fragoso in northern Cuba. Positions alternated from day to day between very shallow waters of one to several meters depth near shore to several hundred meters just offshore. Deep waters extend close to shore in this region. At its final transmitted position, SbRTR372 was in 1 m of water off Cayo Fragoso. We were unable to obtain direct observations of the animals near the coast due to the passage of Hurricane Rita and geo-political restrictions. Colleagues in Cuba were made aware of the situation and the possibility of a stranding, but neither of the dolphins was seen by, or reported to them. It is not known if stenos are common along the north coast of Cuba.

Slope

Steep slopes did not appear to play a major role in determining the movements of the tagged dolphins. Except for Notch, who spent most of his time over relatively flat coastal or shelf waters, the dolphins moved over sea floors with about a 9^{o}-11^{o} slope on average (Table 5). Over a four day period following their turn to the north at Columbus Bank, the dolphins released in May moved along an escarpment leading away from the Bahamas and into more open waters of the Atlantic Ocean. Otherwise, most of their movements were over sea floors with much more gentle slopes. The September dolphins moved over slopes of up to 30^{o} once they reached the north shore of Cuba. Caution is necessary with interpretation of these slope data, as they are measured only at the specific positions where the animals transmitted. Movements across steep slopes between transmissions are not represented in this dataset.

Table 5. Slope (degrees) associated with positions of tagged dolphins.

DOLPHIN:	39381 SbRTY366	57604 SbRTY352	54612 SbRTR307	42480 SbRTR134	42481 SbRTR372
Mean	3.7	10.4	9.5	8.9	10.7
Standard Dev.	3.86	15.55	14.71	5.37	7.64
n	288	220	215	41	42
Minimum	0.1	0.0	0.0	0.4	0.1
Maximum	20.6	74.3	77.7	19.0	30.0

Temperature

The pairs of tagged dolphins released in May and September remained within different, but fairly narrow temperature ranges. The May dolphins remained primarily in waters of 25^{o} to 30^{o}C, with very few records below 25^{o}C and a small number of readings above 30^{o}C (Table 6). The September dolphins remained in warmer waters, typically above 30^{o}C. These temperature profiles were consistent throughout the tracks of each pair of animals.

Table 6. Time-at-temperature data for tagged dolphins. Percentages of all transmitted temperatures occurring within temperature range categories.

DOLPHIN	22-24 ^{o}C	25-27 ^{o}C	28-30 ^{o}C	31-33 ^{o}C	>33 ^{o}C	NO. OF TEMPERATURE RECORDS
54612 SbRTR307	0.2%	53.5%	42.8%	3.6%	0.0%	29,187
57604 SbRTY352	0.1%	43.5%	51.0%	5.4%	0.0%	34,644
42480 SbRTR134	0.0%	0.6%	8.6%	81.5%	9.3%	6,510
42481 SbRTR372	0.0%	0.0%	9.4%	86.8%	3.8%	8,048

Sea surface temperature data varied among the three releases (Table 7). Notch was tracked through the coolest water on average, and through the greatest range of surface temperatures (10^{o}C). The other two pairs moved through warmer average sea surface temperatures, with much smaller temperature ranges than Notch (Table 7). The average surface temperatures for the May and September releases were somewhat cooler than the temperatures recorded by the tags directly (Table 6), but the pattern of warmer waters for the September pair than for the May pair remained consistent across the analyses.

Table 7. Sea surface temperatures (^{o}C) associated with positions of tagged dolphins, obtained remotely from MODIS Aqua thermal-far infrared bands, at resolutions of 4 km and 8 day averages.

DOLPHIN:	39381 SbRTY366	57604 SbRTY352	54612 SbRTR307	42480 SbRTR134	42481 SbRTR372
Mean	21.4	25.5	25.2	29.8	29.7
Standard Dev.	2.86	1.60	1.34	0.52	0.47
n	172	191	186	30	26
Minimum	17.0	22.6	22.6	28.9	28.9
Maximum	27.1	28.2	27.9	30.7	30.9

The possible influence of water temperature masses on the movements of the dolphins was investigated by examining sea surface temperature data relative to where consistent movements or major inflection points in the tracks occurred. During the first week of his track, Notch moved north along the western edge of 24^{o}C water, then crossed over and continued along the eastern edge of this water until he encountered slightly cooler (22^o) water off South Carolina, where he turned to the west (Figure 7a). During weeks #2 and #3, he zig-zagged southward off South Carolina, Georgia, and northern Florida, moving through 17^o -18^o water between the coast and a ribbon of warmer (25^o-26^o) water offshore (Figure 7b,c). In week #4, Notch moved very close to shore, with a large band of 25^o water immediately to his east (Figure 7d). Insufficient temperature data were available to examine the final portion of Notch's track. Interpreting the possible role of water temperature relative to Notch's movements is complicated by the marked shifts in water masses used from week to week, and by the likely influence of the shoreline.

The dolphins released in May moved through the middle of a mass of 26^o C water during the first week of their track, before turning north at Columbus Bank. (Figure 8a). On their northward track during the second week, the animals appeared to move along the edge of 23^o-24^o C water once they moved out of Crooked Island Passage, continuing along this edge as it curved to the southeast during their third week (Figures 8b, 8c). On this course they encountered 25^o-27^o C water, and continued through this temperature (comparable to the temperature at the release site) for the remainder of the track (Figures 8d, 8e). These movements, in the absence of other obvious factors such as shorelines or significant bathymetric features, suggest a preference for waters warmer than 22^{o}C.

The dolphins released in September moved through waters of fairly uniform temperature during the first week of their track (Figure 9a). During the second week, they appeared to demonstrate a preference for 30^o C water over warmer waters to the north and east, but the presence of nearby shorelines and bathymetric features precludes a conclusive statement (Figure 9b).

Figure 7a. Movements of Notch (SbRTY366, PTT 39381) relative to sea surface temperature: tracking week #1.

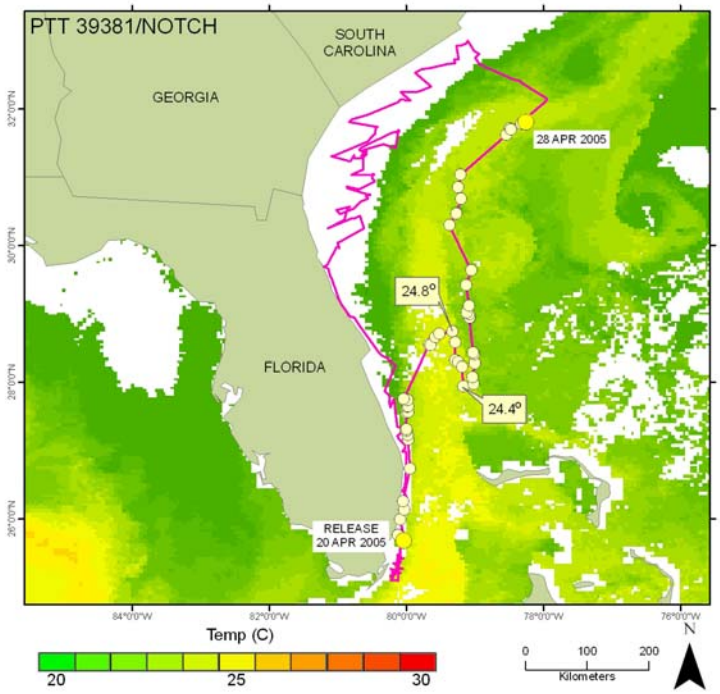


Figure 7b. Movements of Notch (SbRTY366, PTT 39381) relative to sea surface temperature: tracking week #2.

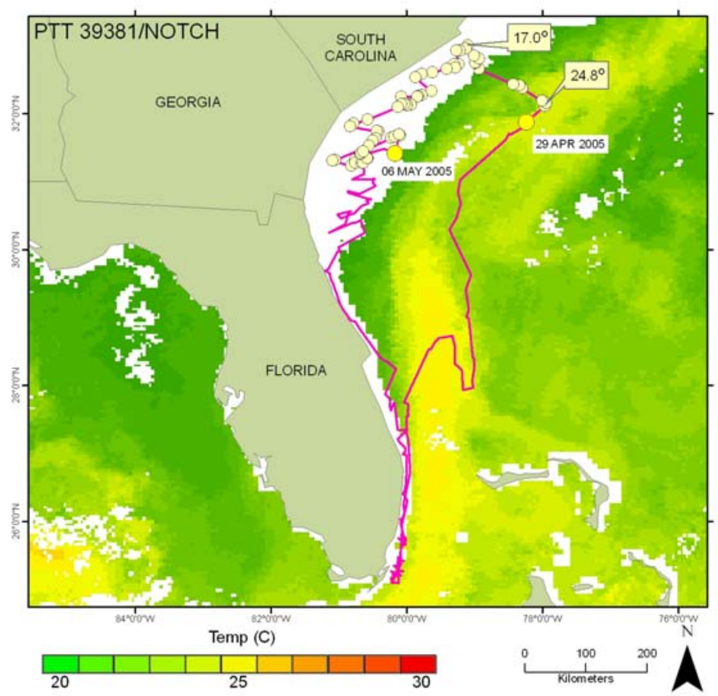


Figure 7c. Movements of Notch (SbRTY366, PTT 39381) relative to sea surface temperature: tracking week #3.

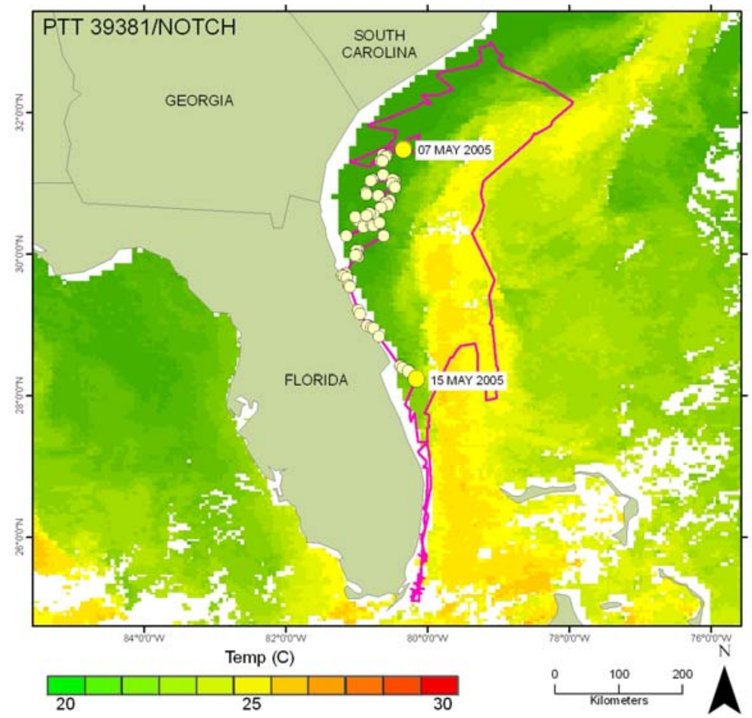


Figure 7d. Movements of Notch (SbRTY366, PTT 39381) relative to sea surface temperature: tracking week #4.

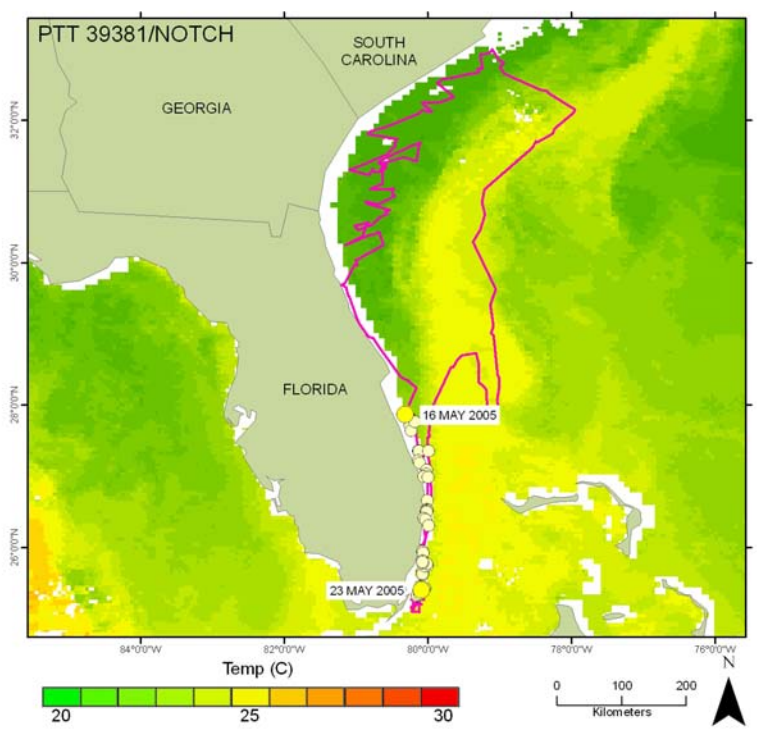


Figure 8a. Movements of dolphins released in May relative to sea surface temperature during tracking week #1.

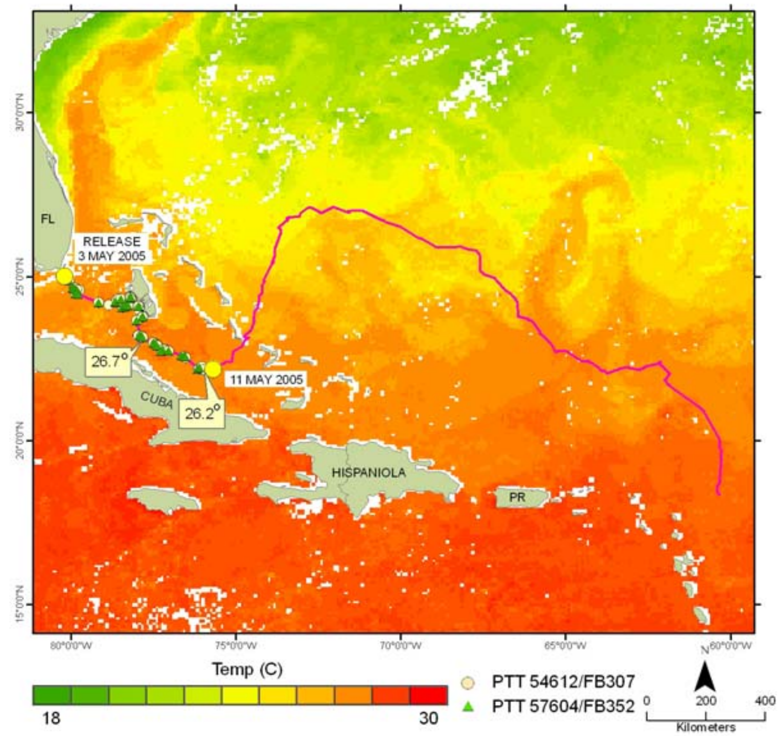


Figure 8b. Movements of dolphins released on 3 May relative to sea surface temperature during tracking week #2.

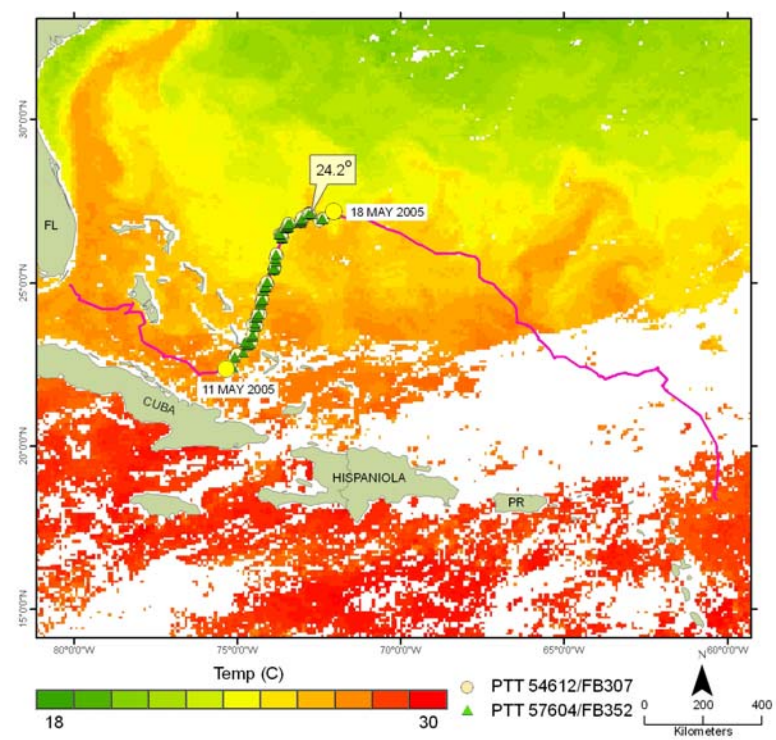


Figure 8c. Movements of dolphins released on 3 May relative to sea surface temperature during tracking week #3.

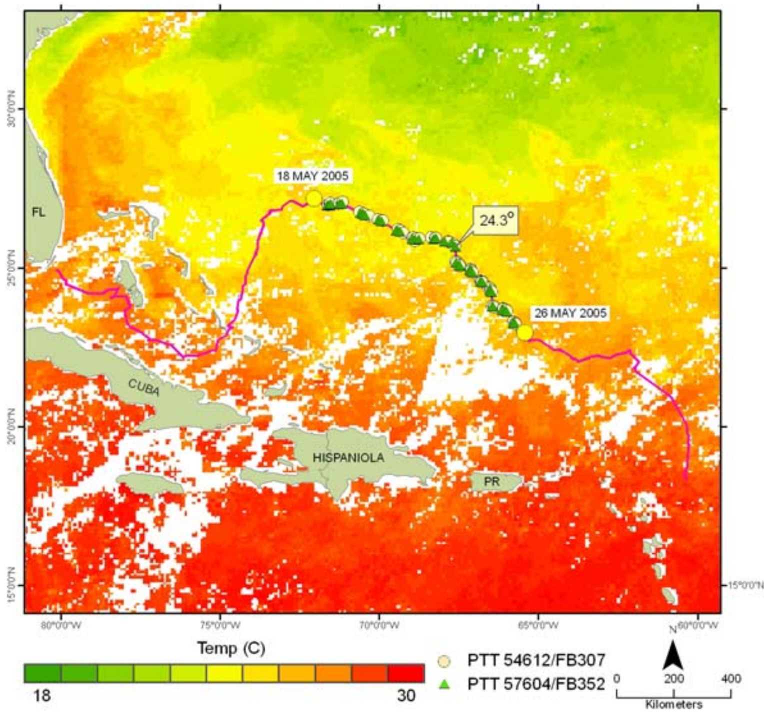


Figure 8d. Movements of dolphins released on 3 May relative to sea surface temperature during tracking week #4.

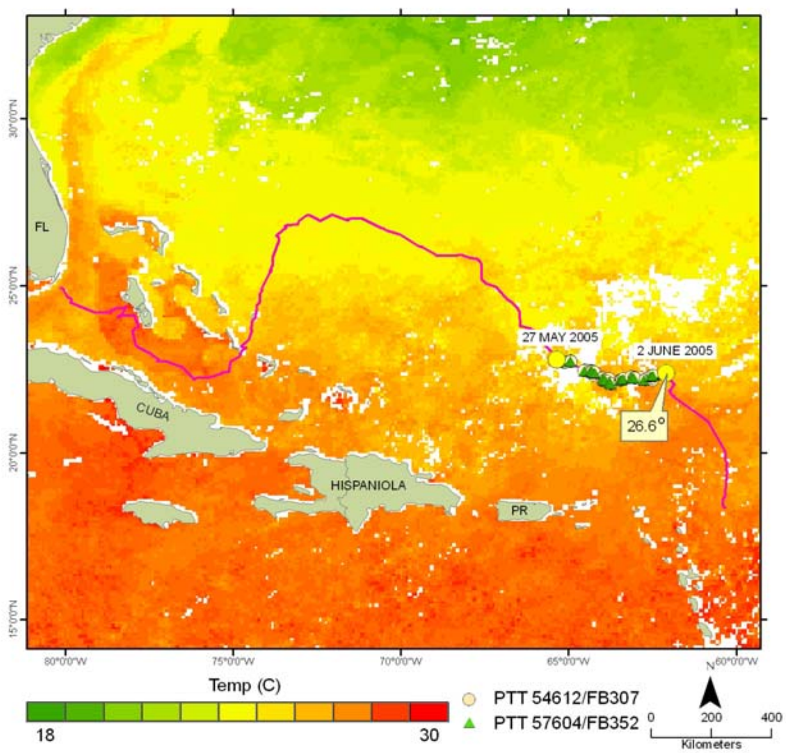


Figure 8e. Movements of dolphins released on 3 May relative to sea surface temperature during tracking week #5.

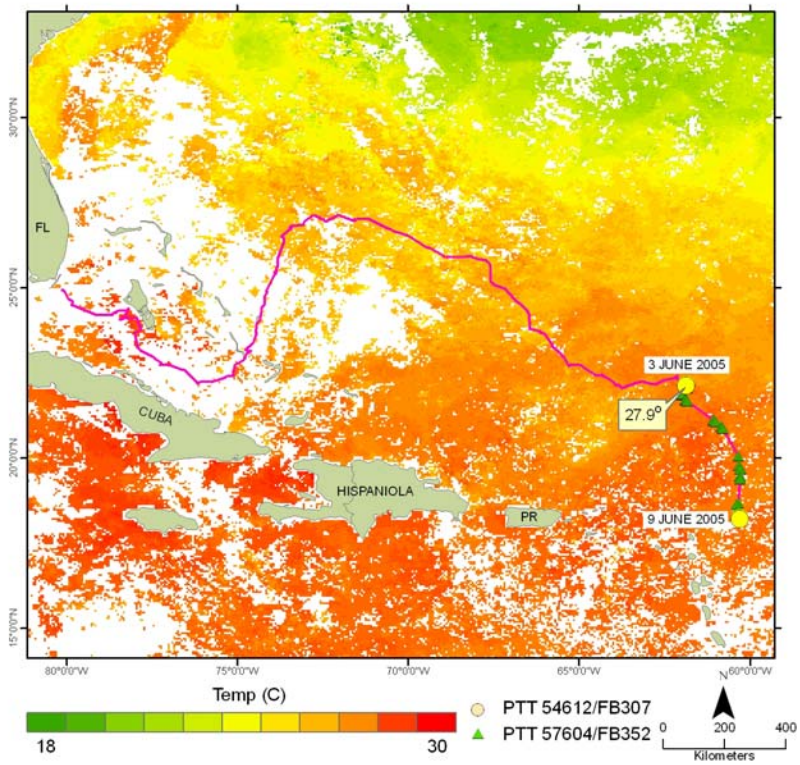


Figure 9a. Movements of dolphins released on 12 September relative to sea surface temperature during tracking week #1.

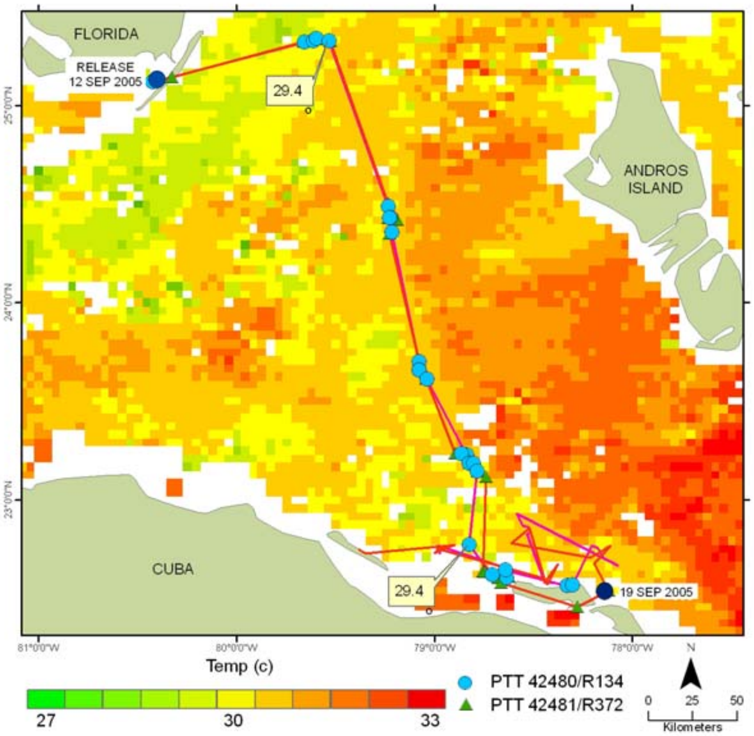
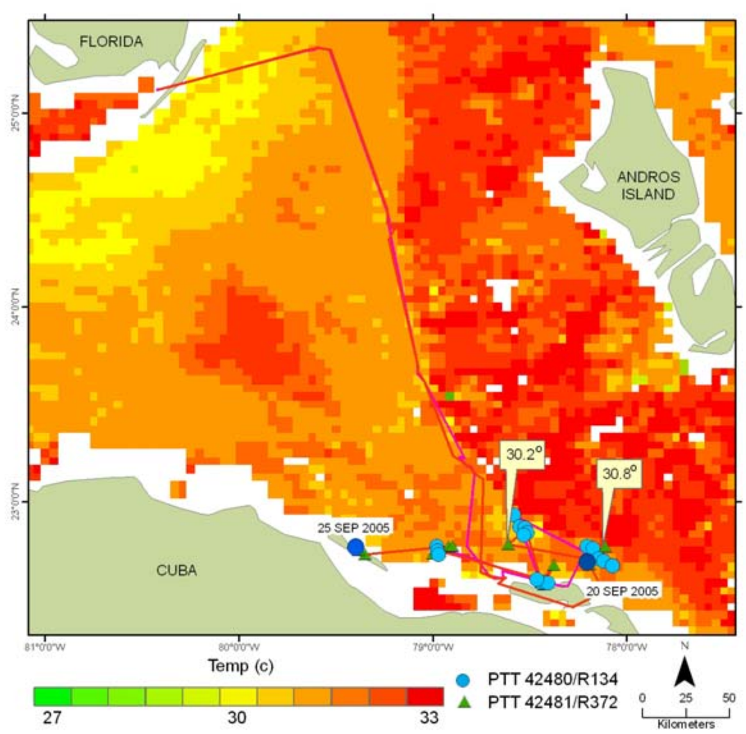


Figure 9b. Movements of dolphins released on 12 September relative to sea surface temperature during tracking week #2.



Rates of Travel

The five tagged dolphins were comparable in their overall rates of travel, averaging about 4-6 km/hr (Table 8; note that all values of 20^+ km/hr were removed from the dataset during filtering). Travel rates for each dolphin varied through the course of the tracks, with four of the five showing declines by the end of the tracks. Notch's travel rates declined during the second half of his track, to an average of about 2 km/hr during the last few days (Figure 10a). FB307's travel rates appeared to increase through the mid-point of its track, and then declined to less than 2 km/hr on the final day of tracking (Figure 10b). FB352 demonstrated a fairly consistent oscillation in travel rates throughout its track, centered on about 4-5 km/hr (Figure 10c). R134 and R372 both exhibited declines in travel rates to about 2 km/hr on the final tracking day as they moved along the north shore of Cuba (Figures 10d, 10e).

Table 8. Rate of movement (km/hr) associated with positions of tagged dolphins.

DOLPHIN:	39381 SbRTY366	57604 SbRTY352	54612 SbRTR307	42480 SbRTR134	42481 SbRTR372
Mean	4.1	4.9	5.7	4.4	3.9
Standard Dev.	3.09	3.17	3.61	4.16	2.22
n	274	213	203	40	38
Minimum	0.1	0.0	0.0	0.2	0.0
Maximum	17.4	19.0	18.0	19.0	8.6

Figure 10a. Travel rates for Notch (SbRTY366, PTT 39381), April-June 2005.

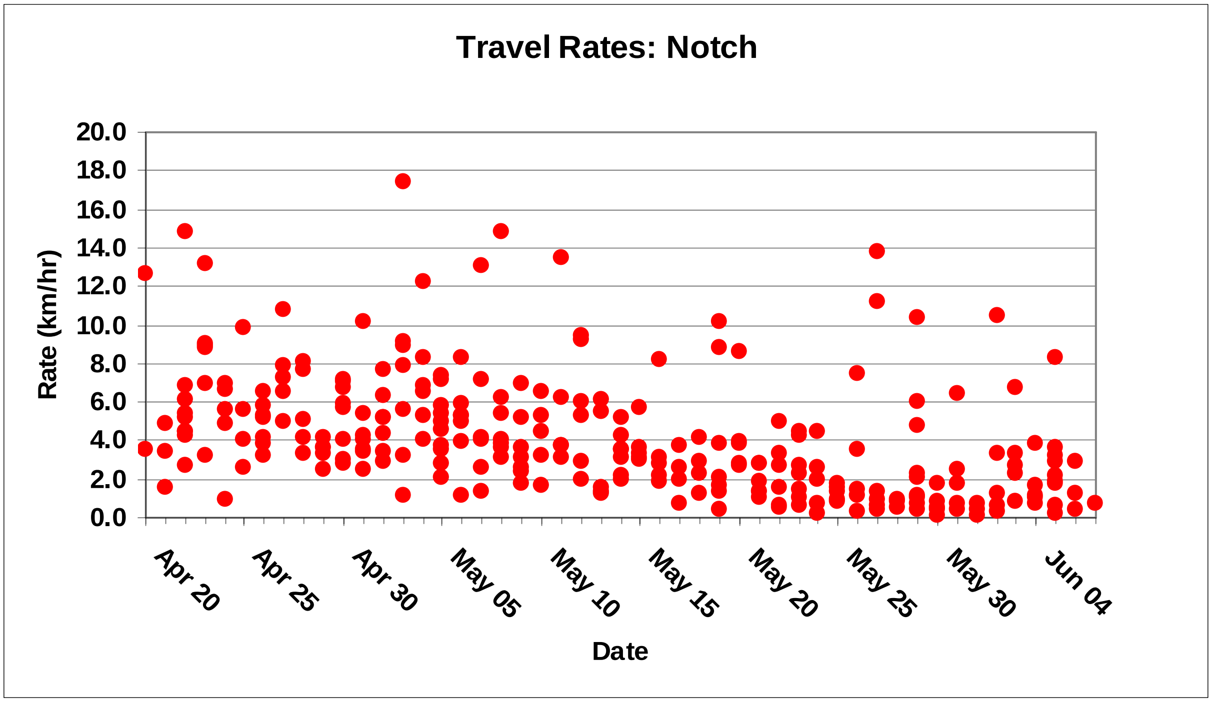


Figure 10b. Travel rates for SbRTR307 (PTT 54612), May-June 2005.

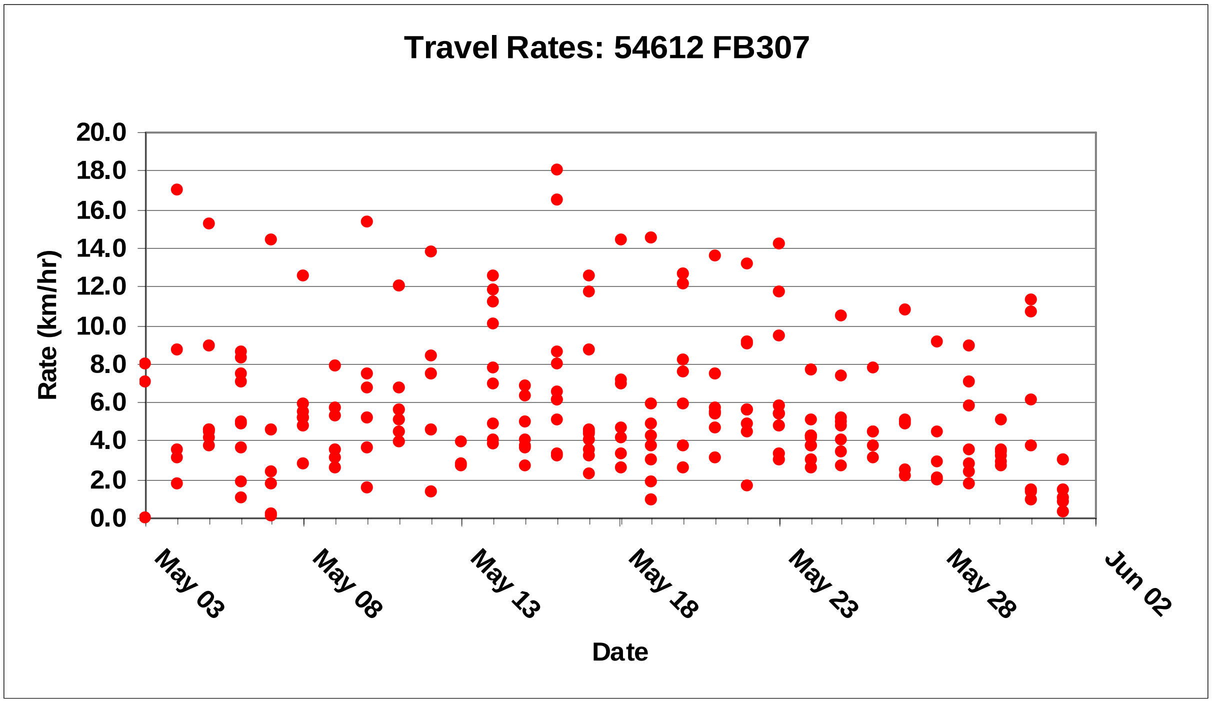


Figure 10c. Travel rates for SbRTY352 (PTT 57604), May-June 2005.

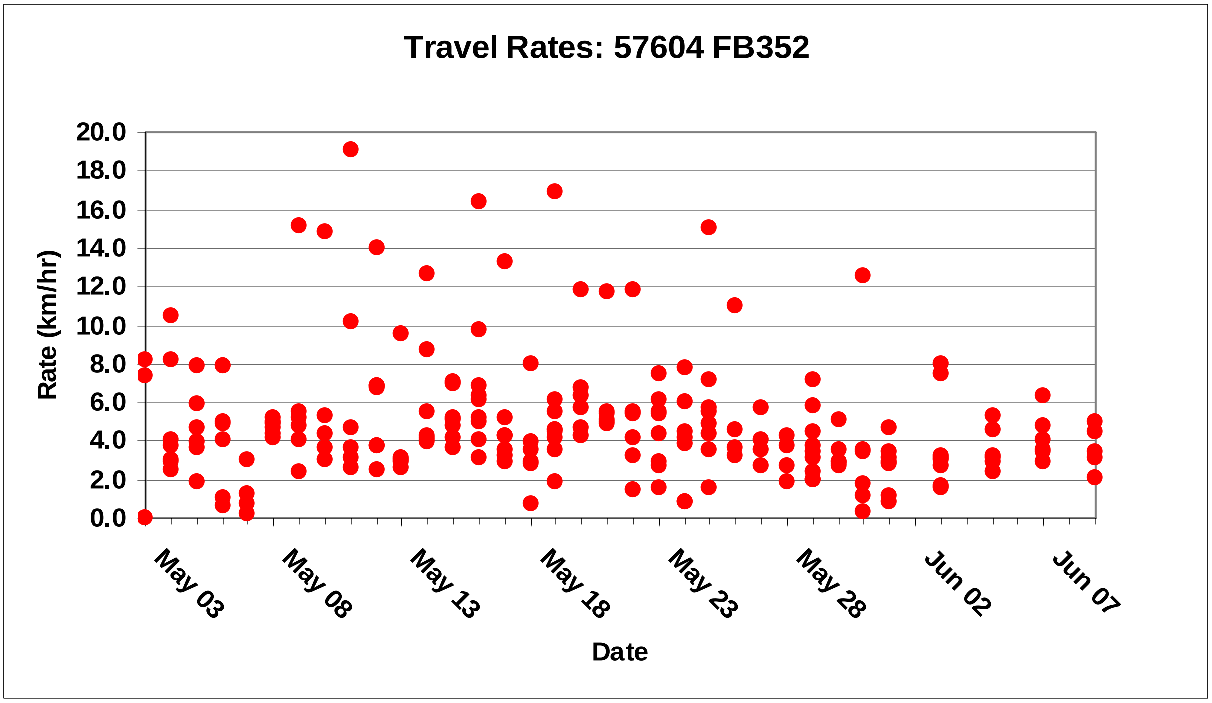


Figure 10d. Travel rates for SbRTR134 (PTT 42480), September 2005.

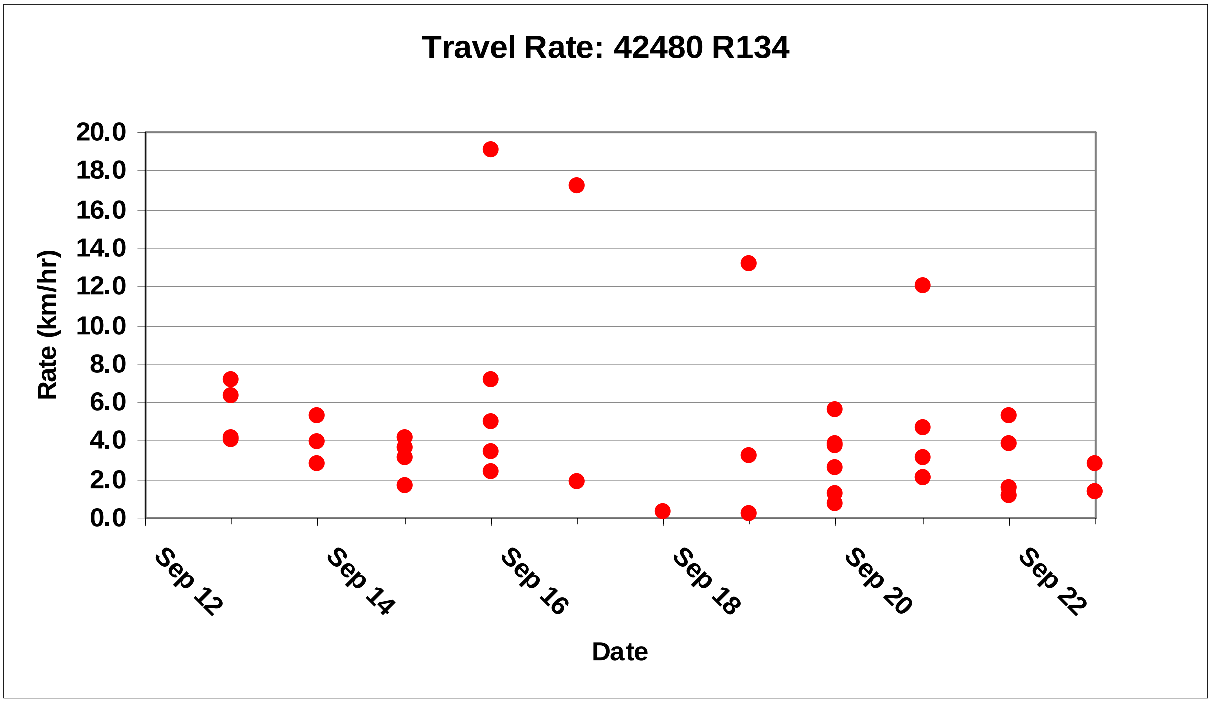
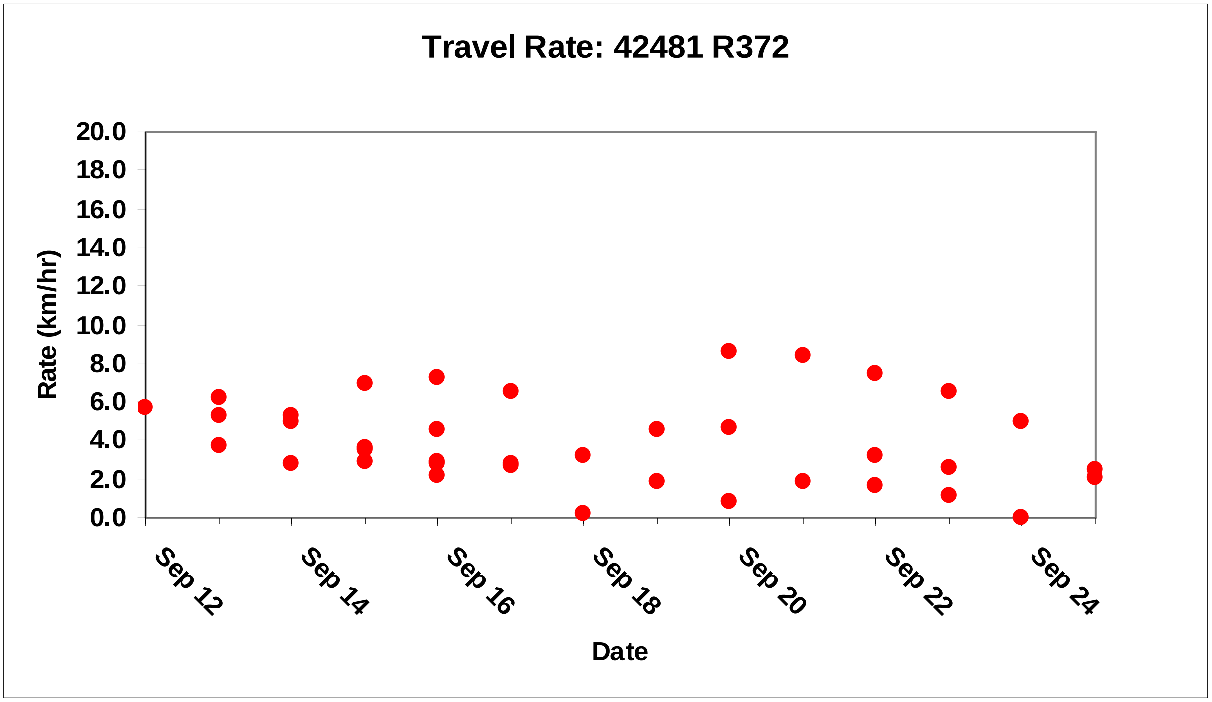


Figure 10e. Travel rates for SbRTR372 (PTT 42481), September 2005.



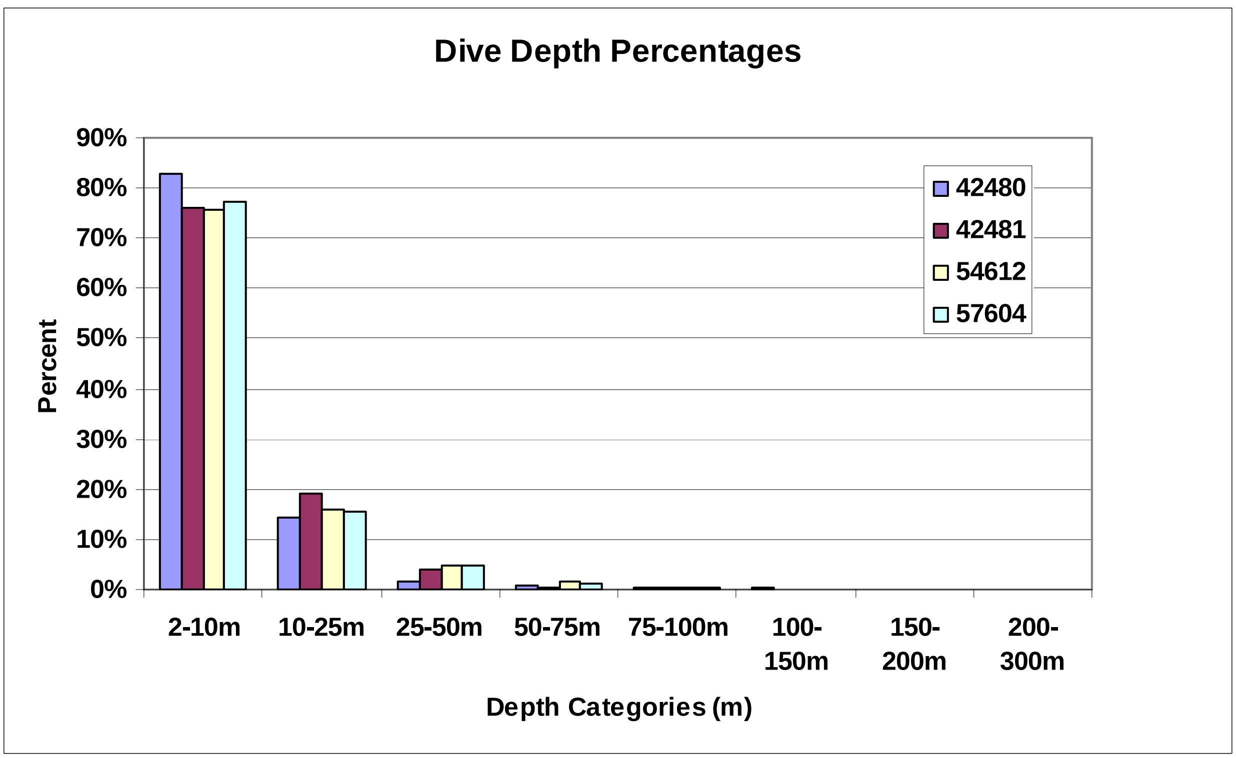
Dive Patterns

Dive data are available from the four Splash tags deployed in May and September. The numbers of dive depths measured for each dolphin, considering only dives of greater than 2 m depth, ranged from 2,628 to 13,939. All four of the dolphins tended to remain fairly close to the surface, rarely diving below 50 m. More than 91% of the dolphins' dives greater than 2 m deep were to less than 25 m, with more than 75% reaching no more than 10 m (Table 9, Figure 11). One dolphin each from the May and September releases made occasional dives to depths greater than 100-150 m, reaching 200-300 m (54612 = 2 dives; 42480 = 1 dive).

Table 9. Percentage of dives > 2 m occurring within depth categories.

DOLPHIN	2-10m	10-25m	25-50m	50-75m	75-100m	100-150m	150-200m	200-300m
54612	75.82%	15.79%	4.85%	1.45%	0.31%	0.06%	0.00%	0.01%
57604	77.42%	15.64%	4.62%	1.16%	0.30%	0.10%	0.00%	0.00%
42480	82.71%	14.25%	1.78%	0.68%	0.27%	0.23%	0.04%	0.04%
42481	76.02%	19.28%	3.99%	0.42%	0.26%	0.03%	0.00%	0.00%

Figure 11. Comparison of overall dive depths across all four dolphins.



All four dolphins demonstrated comparable dive depth profiles relative to approximate time of day. In all cases, the number of deeper dives (>25 m) was smallest during Day (Figures 12a, 12b, 12c, 12d). The deepest dives were made during Dusk, Night, and Dawn, but these dives were not frequent, and not very deep. It should be noted that the releases occurred during different times of the year, and the May dolphins moved well to the east of the Eastern time zone. The analyses reported here have not been adjusted relative to true daylength.

Figure 12a. Distribution of dive depths throughout the day for SbRTR307 (PTT 54612).

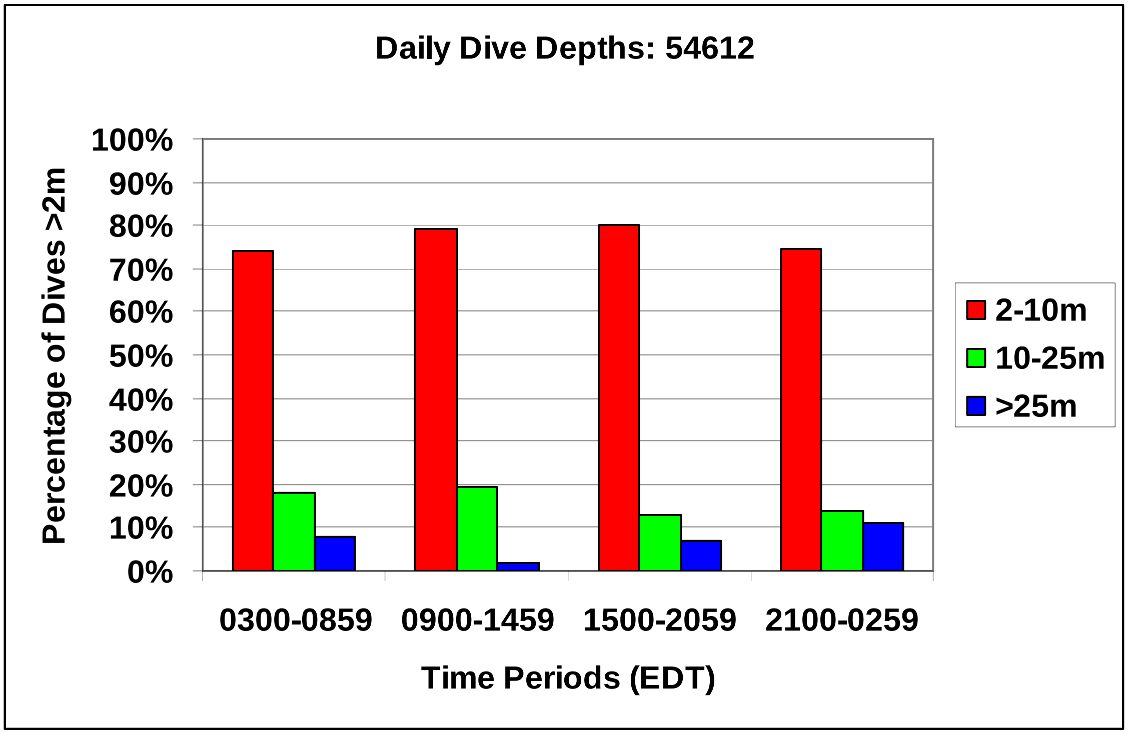


Figure 12b. Distribution of dive depths throughout the day for SbRTY352 (PTT 57604).

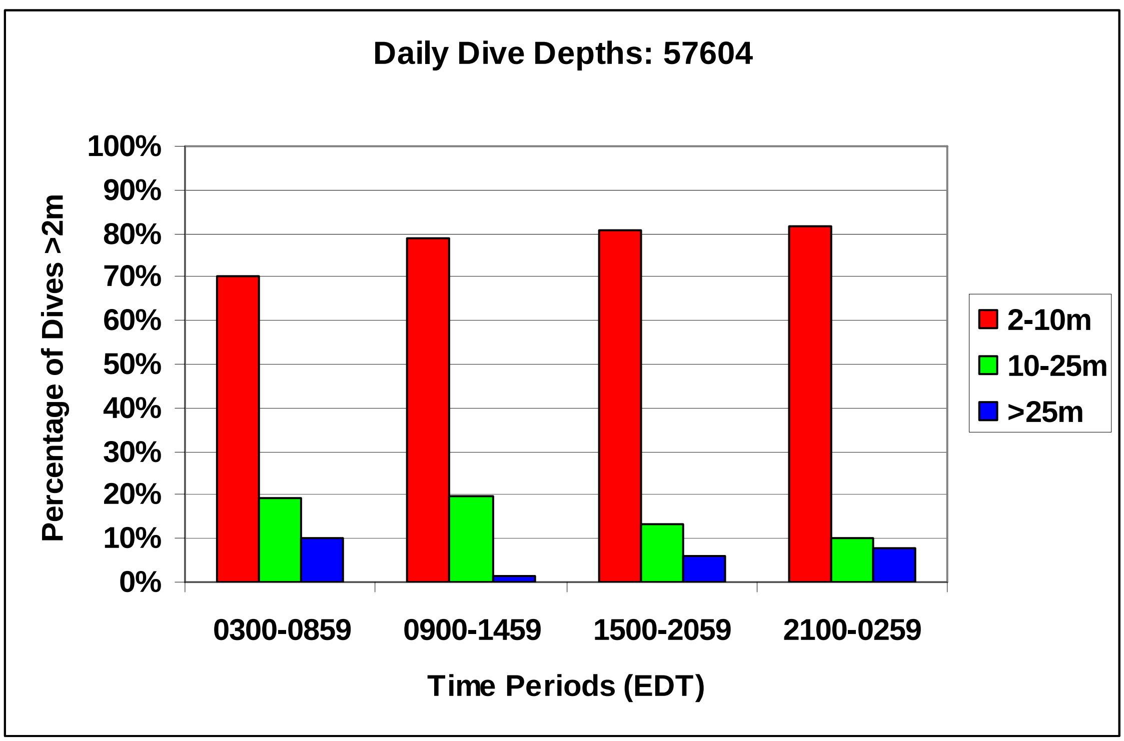


Figure 12c. Distribution of dive depths throughout the day for SbRTR134 (PTT 42480).

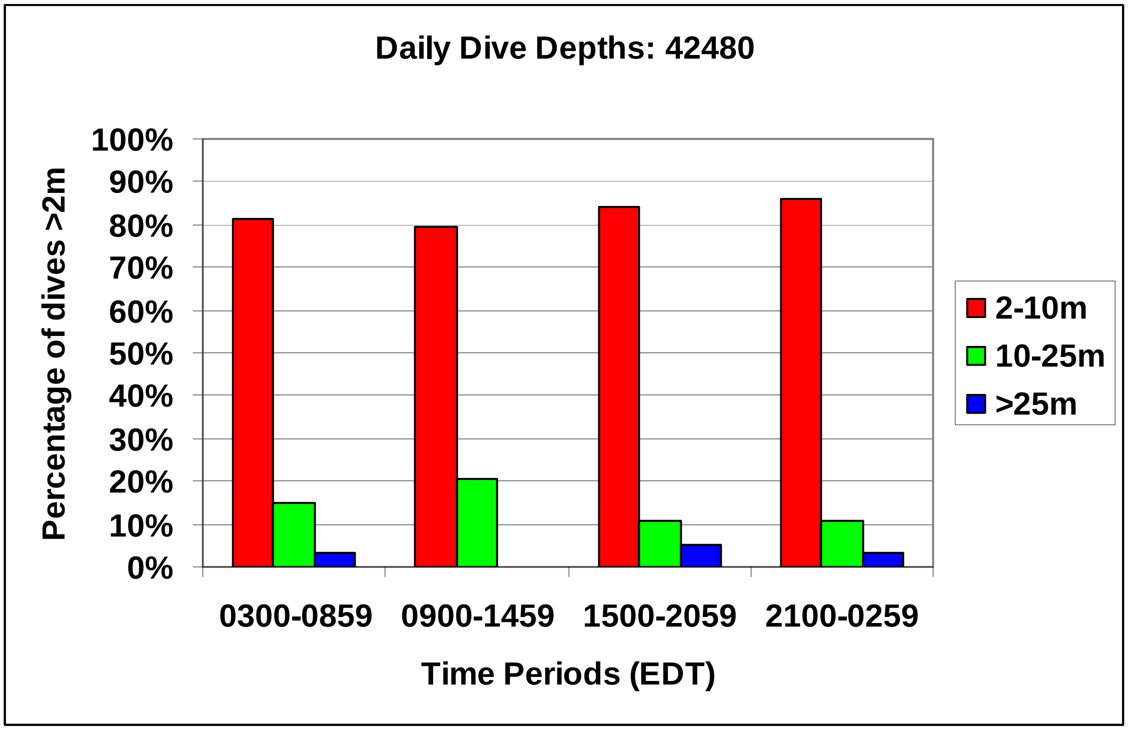
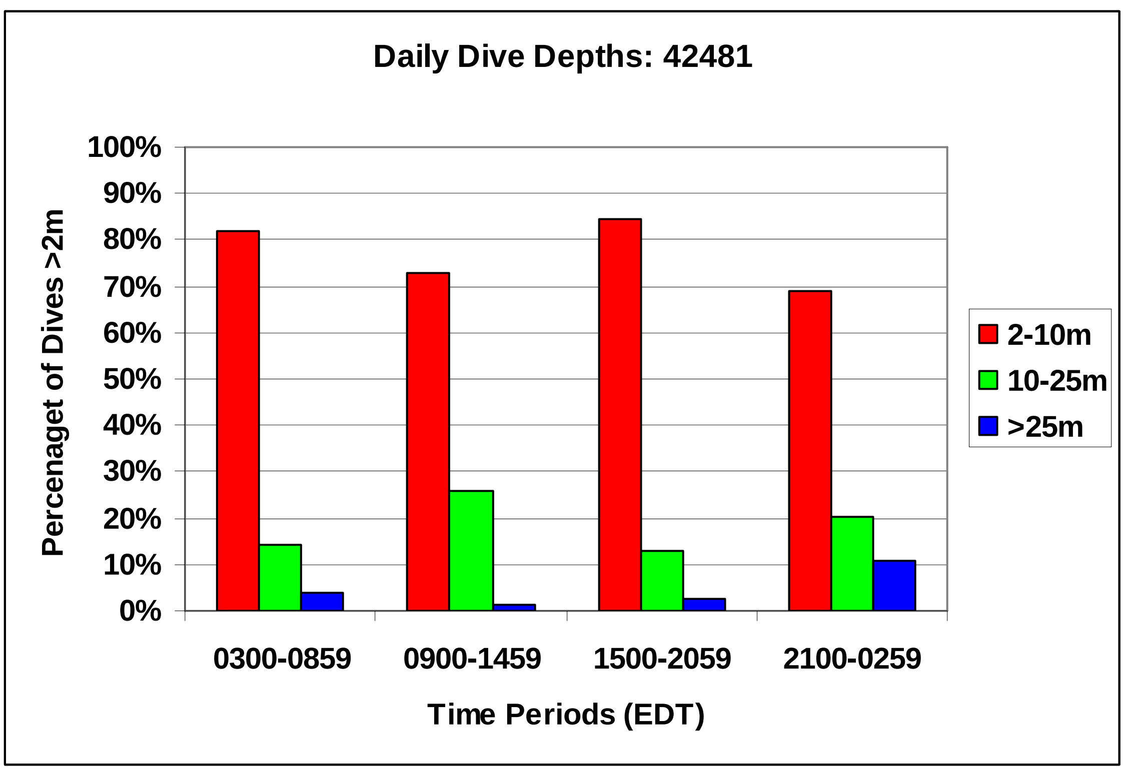


Figure 12d. Distribution of dive depths throughout the day for SbRTR372 (PTT 42481).



The depths to which dolphins dive can serve as an indicator of the condition of the animal. Dive patterns changed through the course of tracking for each dolphin, but it was not immediately obvious whether these changes were due to environmental factors or changes in the abilities of the animals. To investigate one aspect of the relative contributions of environmental features and animal condition on dive patterns, maximum daily dive depths were compared to maximum available water depth recorded for each dolphin, to examine the animals' use of the water column over time. Water depths for the positions provided by Argos each day were compared, and the deepest depth for each dolphin was selected. Given the movements of the animals, this was not always the deepest water through which the animals passed during the day, but typically it was representative. Ideally, the value for deepest dive of the day would have been used for this analysis, but this Splash tag feature did not function properly on any of the four tags deployed (it is apparently a general problem with this tag design). As a proxy for a daily maximum dive depth data point, the deepest histogram bin of the day for each dolphin was used for the analyses. Because of the inherent imprecision in the data indicated above, these data were not subjected to statistical analyses. Instead, the results are presented graphically below (Figures 13a, 13b, 13c, 13d).

Not surprisingly, all four of the dolphins tended to perform their deepest dives when the water was deepest. They did not appear to be diving to the sea floor except possibly when the waters were fairly shallow, less than 100-200 m deep (Figures 13a, 13b, 13c, 13d).

When the water was sufficiently deep, SbRTR307 typically dove at least once each day to depths in excess of 100 m (Figure 13a). On the last day of tracking, this dolphin dove to more than 300 m, in waters that were nearly 6,000 m deep. Over the same 30-day period, SbRTY352, released with SbRTR307, followed a similar pattern (Figure 13b). However, the track of SbRTY352 continued for several additional days, and over this time the deepest daily dives steadily decreased in magnitude, to no more than 50 m on the final day for which data were available.

The dive patterns for the dolphins released in September were somewhat more complex. As they approached the north shore of Cuba, maximum dive depth appeared to exceed available water depth. This is believed to represent movements from near-shore shallows to the nearby submarine trench. Both animals continued to make daily deep dives in excess of 75 m through the ends of the tracks.

Figure 13a. Maximum daily dive depth bin relative to maximum daily water depth for filtered positions for dolphin SbRTR307 (PTT 54612). This figure is an indication of the dolphin's use of the available water column. The specific timing of the deepest dives does not necessarily exactly coincide with the available position and associated depth data.

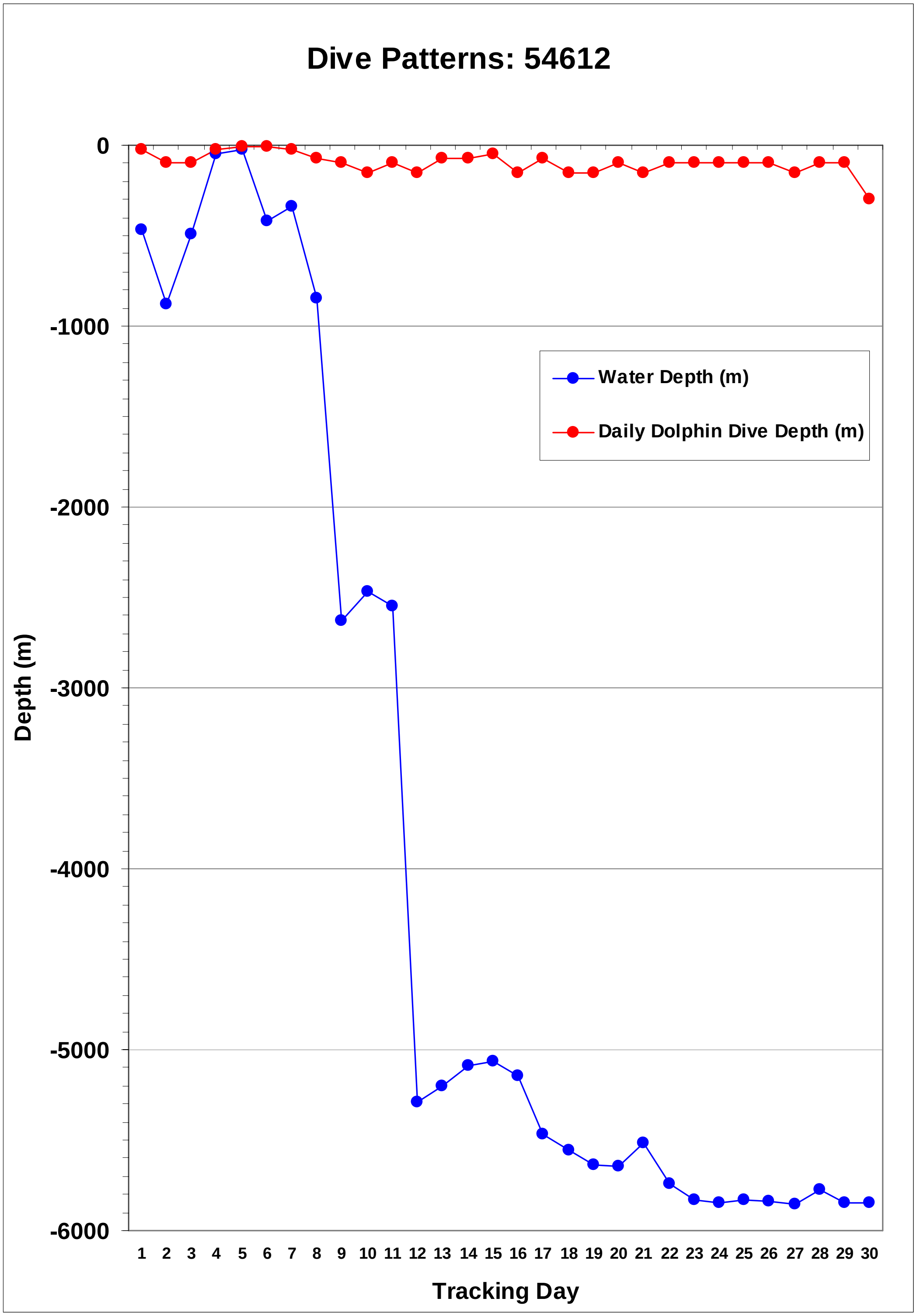


Figure 13b. Maximum daily dive depth bin relative to maximum daily water depth for filtered positions for dolphin SbRTY352 (PTT 57604). This figure is an indication of the dolphin's use of the available water column. The specific timing of the deepest dives does not necessarily exactly coincide with the available position and associated depth data.

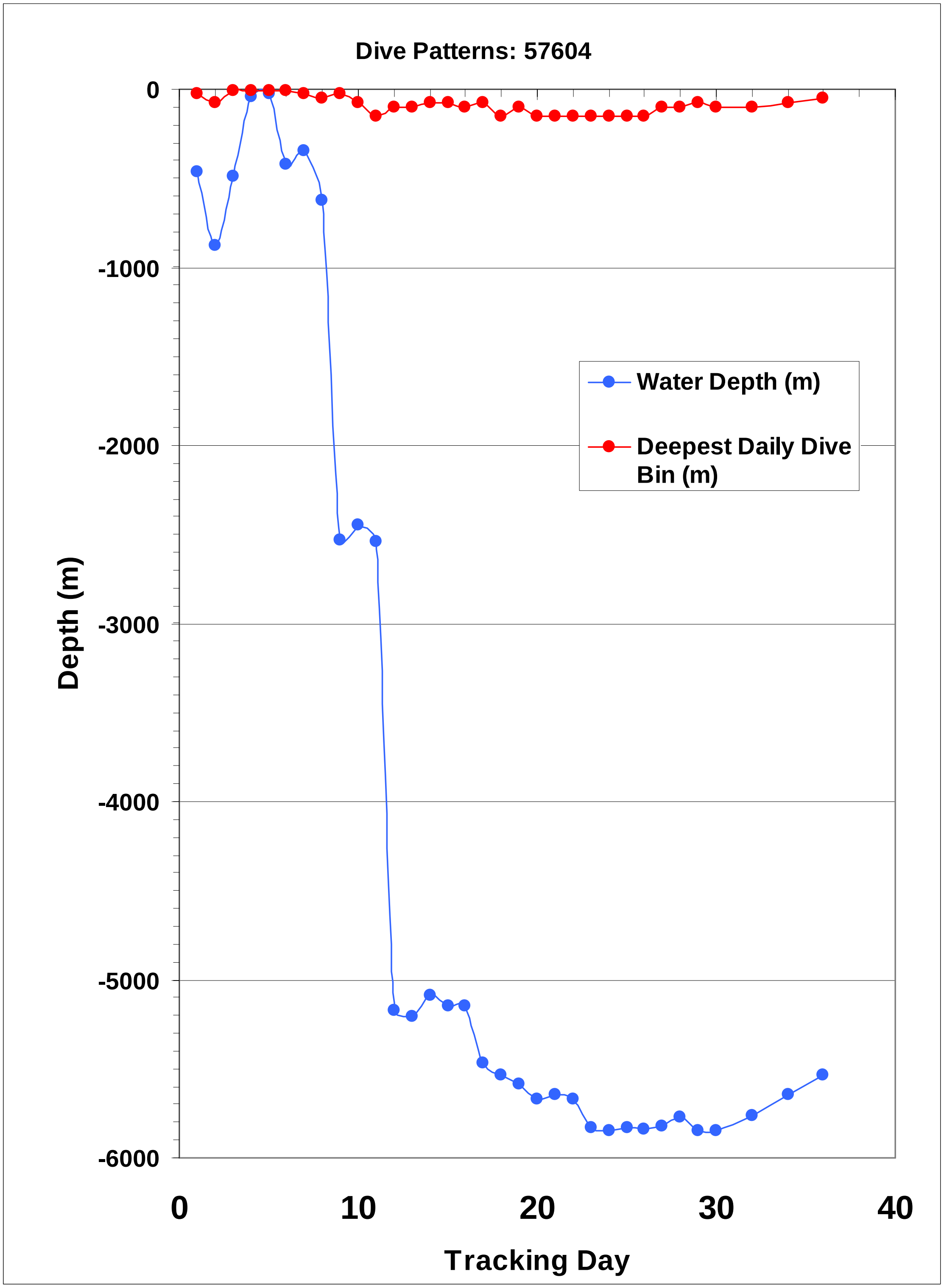


Figure 13c. Maximum daily dive depth bin relative to maximum daily water depth for filtered positions for dolphin SbRTR134 (PTT 42480). This figure is an indication of the dolphin's use of the available water column. The specific timing of the deepest dives does not necessarily exactly coincide with the available position and associated depth data.

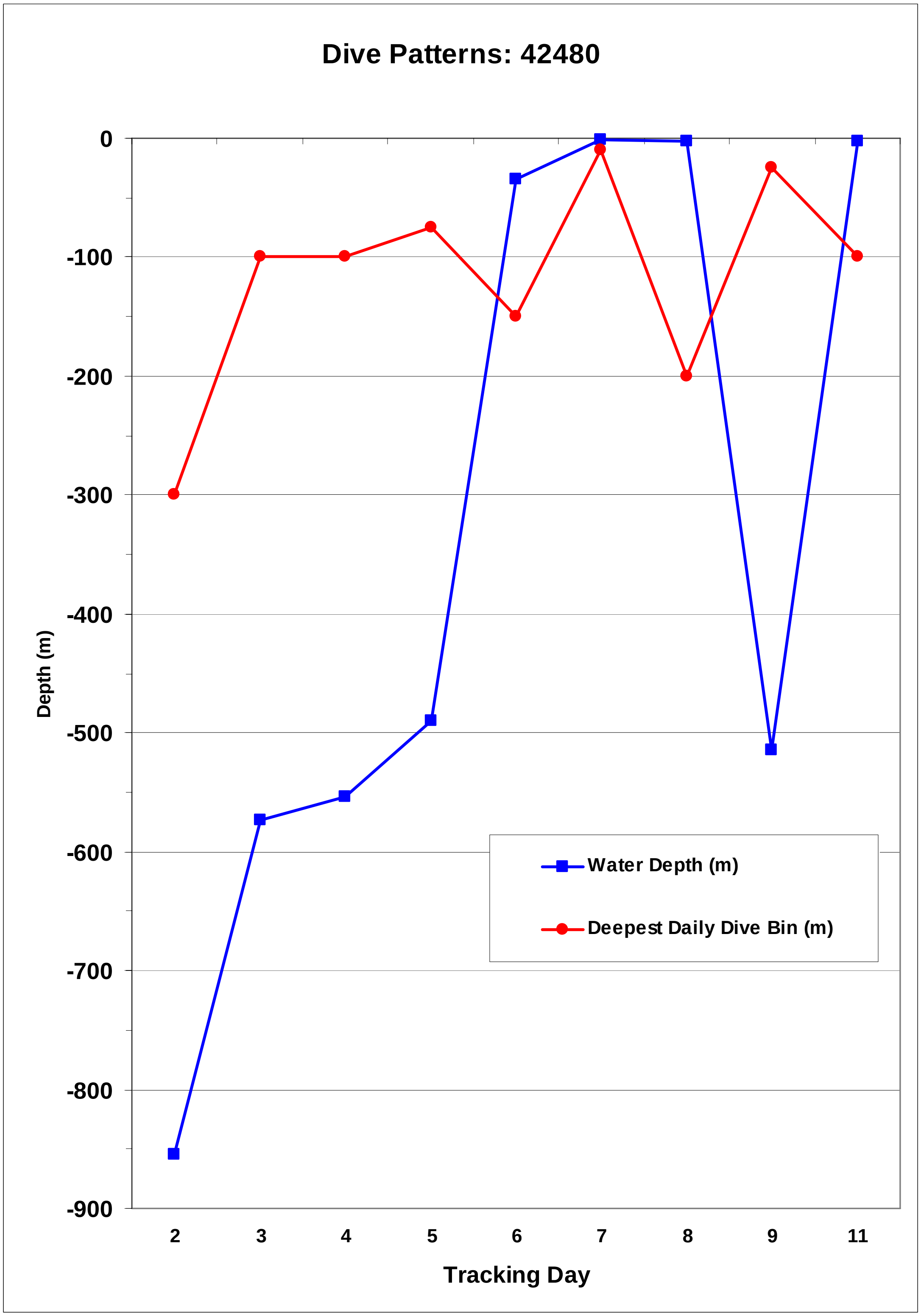
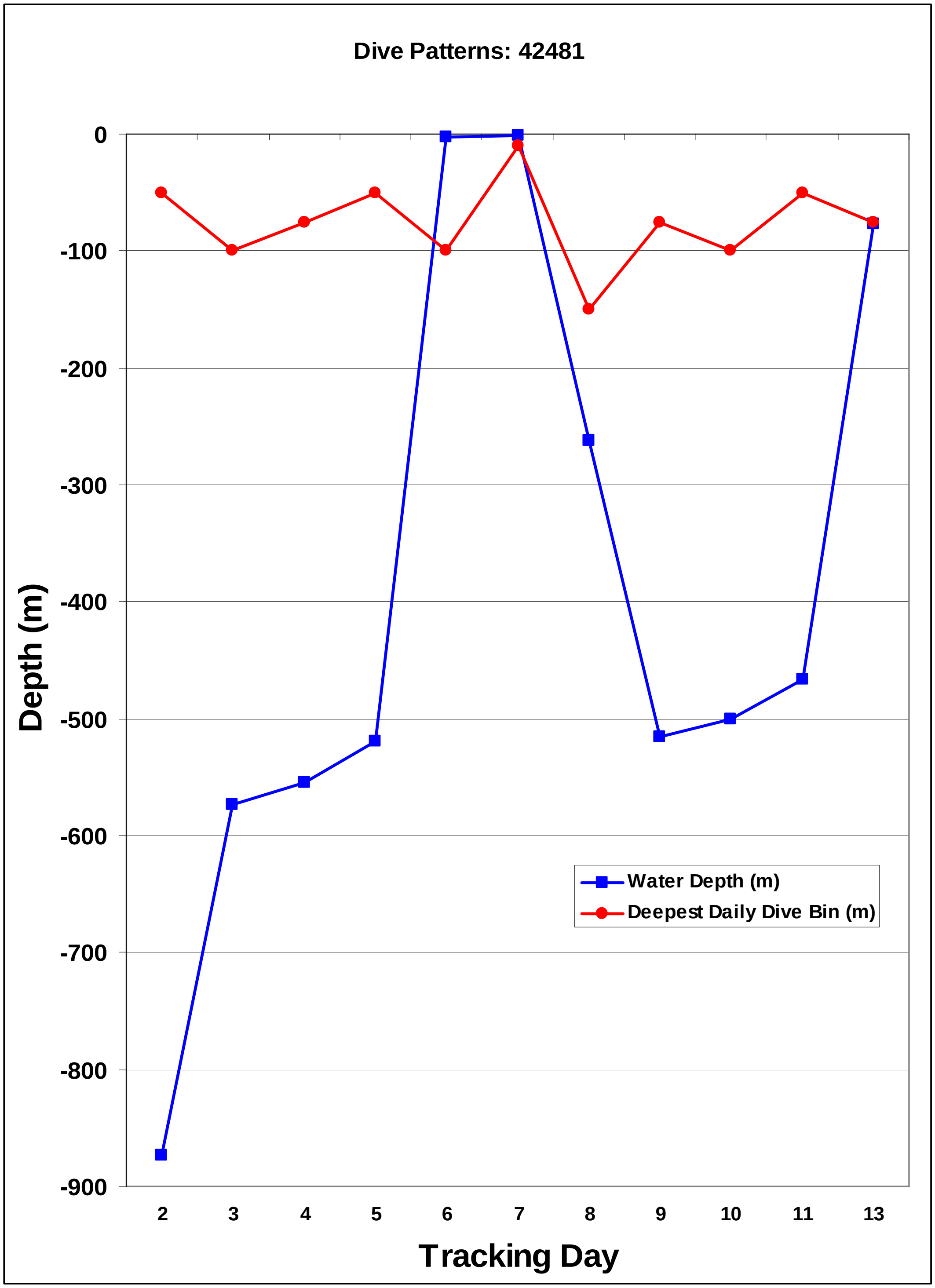


Figure 13d. Maximum daily dive depth bin relative to maximum daily water depth for filtered positions for dolphin SbRTR372 (PTT 42481). This figure is an indication of the dolphin's use of the available water column. The specific timing of the deepest dives does not necessarily exactly coincide with the available position and associated depth data.

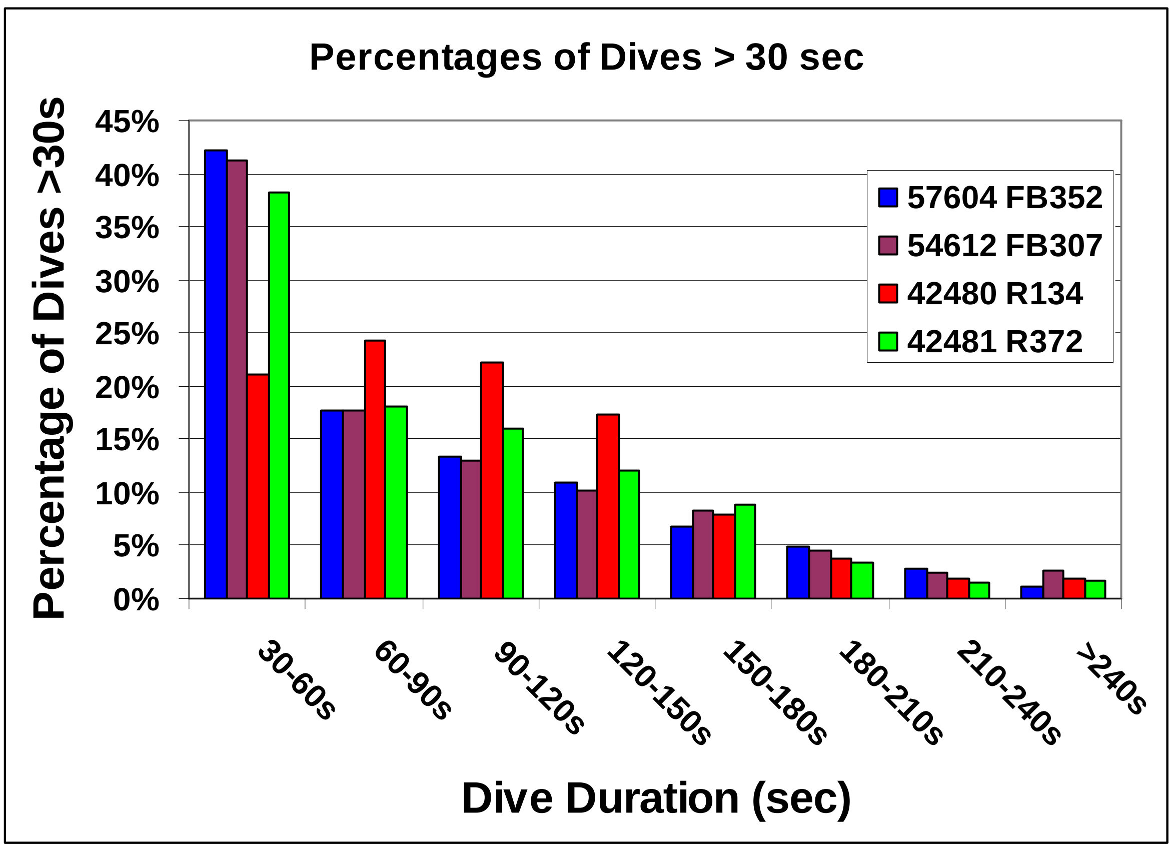


Dive duration histogram data were collected for 25,101 dives of more than 30 sec, ranging from 1,254 to 11,386 measures per dolphin. Three of the dolphins demonstrated very similar profiles (Table 10, Figure 14). For SbRTY352, SbRTR307, and SbRTR372, 72%-73% of all dives > 30 sec were of no more than 120 sec; 67% of dives by SbRTR134 fit these criteria. Few dives by any of the dolphins exceeded 240 sec. Both of the dolphins released in May made a few dives of greater than 420 sec (SbRTRFB307 = 2 dives; SbRTY352 = 5 dives). SbRTR134's longest dive was 330-360 sec. SbRTR372's longest dives were 270-300 sec.

Table 10. Percentage of dives > 30 sec occurring within dive duration categories.

DOLPHIN	30-60s	60-90s	90-120s	120-150s	150-180s	180-210s	210-240s	>240s
57604 SbRTY352	42.25%	17.72%	13.36%	10.96%	6.79%	4.92%	2.84%	1.16%
54612 SbRTR307	41.17%	17.73%	12.97%	10.22%	8.32%	4.57%	2.41%	2.60%
42480 SbRTR134	21.02%	24.33%	22.13%	17.25%	7.84%	3.77%	1.80%	1.86%
42481 SbRTR372	38.28%	18.10%	16.03%	11.96%	8.85%	3.43%	1.59%	1.75%

Figure 14. Overall dive duration profiles for tagged dolphins.



Data on respiratory patterns can provide insights into the health of dolphins. Dive duration data were examined as indirect measures of respiratory patterns. Changes over time were examined by comparing profiles across three-day blocks of time. Dive duration profiles varied for each dolphin over the course of the tracks (Figures 15a, 15b, 15c, 15d). SbRTR307 made more long dives (> 180 sec) during the middle of the tracking period, with higher proportions of dives of 120 sec or less at the beginning and end of the track (Figure 15a). Over the last 4 blocks, there was a downward trend in the proportion of the briefest dives, 30-60 sec, associated with an increase in the proportion of intermediate dives of 60-150 sec. SbRTY352 showed a somewhat similar pattern, making more long dives (> 180 sec) during the middle of the tracking period, with higher proportions of dives of 120 sec or less at the beginning and end of the track (Figure 15b). Unlike SbRTR307, the trend towards the end of the track involved a higher proportion of the briefest dives, but the animal still performed dives in excess of 180 sec even during the final tracking period. SbRTR134 made the highest proportion of long dives during the second period, with a trend toward increasing proportions of intermediate dives during the track (Figure 15c). SbRTR372 made its longest dives during the second period, with more intermediate dives during the middle periods (Figure 15d). This was followed by a dramatic increase in the proportion of the briefest dives, with a concomitant decrease in deep and intermediate-length dives, during the final period.

Figure 15a. Dive duration profiles for three-day periods for SbRTR307 (PTT 54612).

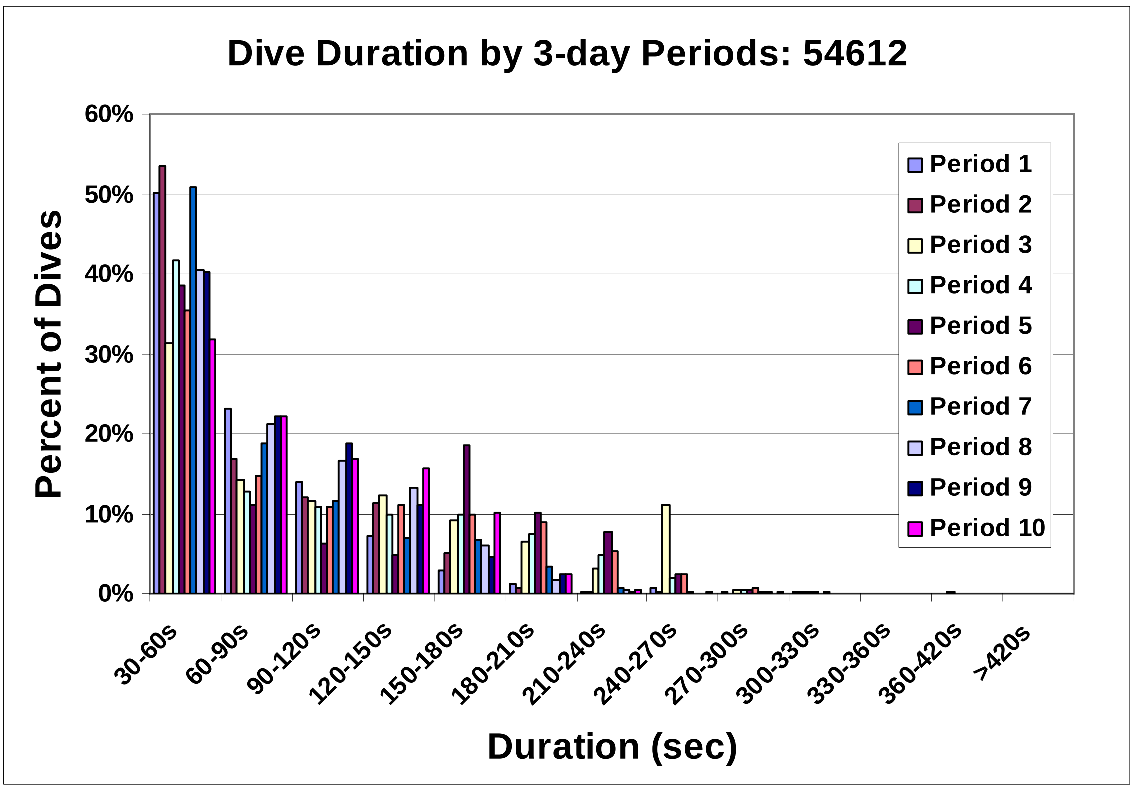


Figure 15b. Dive duration profiles for three-day periods for SbRTY352 (PTT 57604).

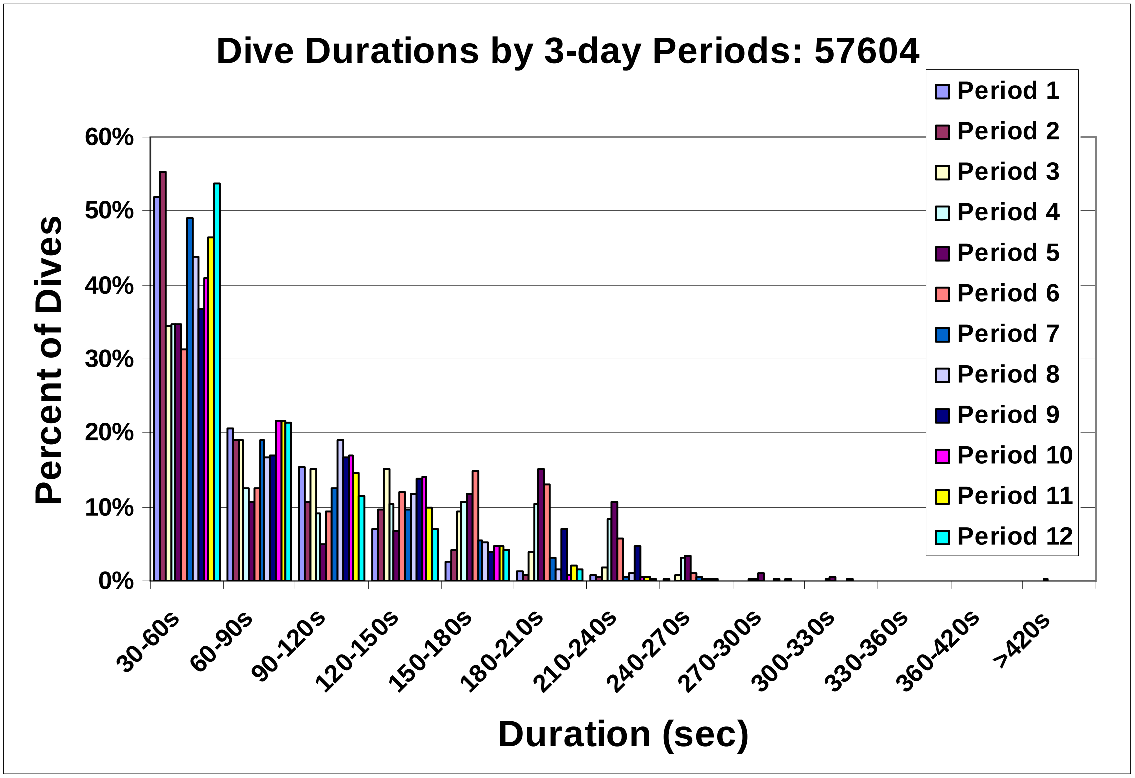


Figure 15c. Dive duration profiles for three-day periods for SbRTR134 (PTT 42480).

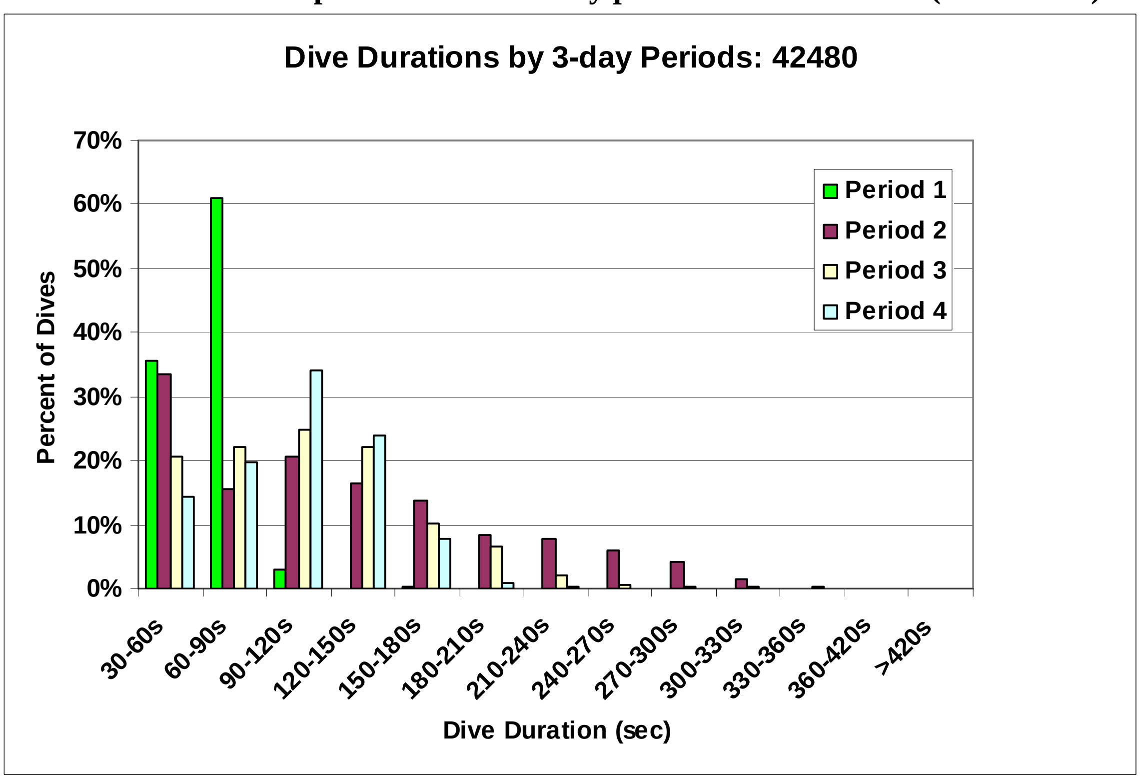
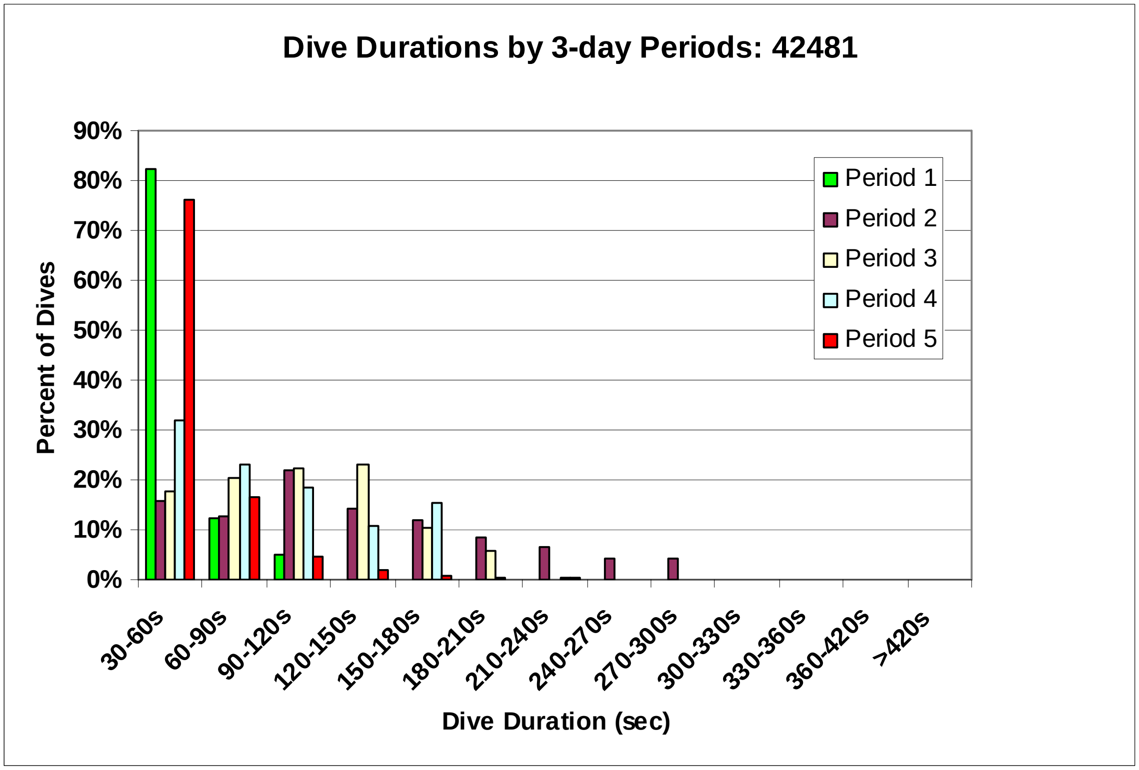


Figure 15d. Dive duration profiles for three-day periods for SbRTR372 (PTT 42481).



Social Patterns

Only one member of the pair of dolphins released in April was tagged, so no information on social patterns is available. During both the May and September releases, the pairs of tagged dolphins appeared to remain together throughout the tracks. Direct observations of the seven dolphins released in May found them to be in a tight group off the west shore of Andros Island four days post-release (Figures 6a, 6b). Distances between members of pairs measured when Argos positions were available for both dolphins within a period of five minutes provided additional support for the animals remaining together throughout tracking. On average the Argos positions of the dolphins released in May were within 2.99 km of each other (s.d. = 4.289, n = 126). Given the precision limitations of the satellite-derived positions, it seems likely that the animals were often closer to one another than indicated from tracking data. At 1430 on 7 May 2005, the dolphins were photographed in very close proximity to one another (within a few meters) near Andros Island (Figures 6a, 6b). At 0801 on the same day, their separation according to Argos position data was 348 m, and about 1.5 hours after the photographs, Argos positions placed them 539 m apart. Either the dolphins came together from several hundred meters apart prior to the photographs and then separated again shortly thereafter, or the satellite data exaggerated the spread. Similar separation values were obtained for the dolphins released in September (mean = 3.61 km, s.d. = 4.751, n = 29). No obvious patterns of increasing or decreasing separation over time were noted. These separations seem remarkably small when considered in light of distances traveled, the sizes of the basins in which they traveled, the time periods (weeks) over which relatively consistent distances between animals were maintained, the precision of Argos position estimates, and the parameters of the position-filtering algorithm.

DISCUSSION

No formally-accepted criteria exist for evaluating the success of a dolphin rehabilitation case. In the absence of established criteria, we used the following "working" measure of success:

> *Following release, the dolphin exhibits patterns of movements, habitat use, locomotion, behavior, and social interactions typical for the species for a minimum of 4 weeks.*

When added to the two-week standard clearance time at the rehabilitation facility prior to release, six weeks seems like a reasonable minimum amount of time for a dolphin to demonstrate its ability to survive and thrive post-treatment. It is understood that constraints on follow-up monitoring may limit abilities to collect the necessary information to make this evaluation, and that assessments may need to be made on the basis of less than complete information. For example, tags may fail, or the animal may move outside of range for monitoring before 28 days of tracking have been completed.

Some species, such as stenos, may not have been studied sufficiently in the wild to define patterns typical for the species. Little information is available on the distribution and behavior of free-ranging rough-toothed dolphins in the northwest Atlantic Ocean -- rough-toothed dolphins are not even listed in the *U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments* prepared by NOAA/National Marine Fisheries Service (Waring *et al*. 2006) as a species that occurs in the Atlantic. In the absence of information about expected patterns for this species in the Atlantic Ocean it is difficult to evaluate the ranging and dive patterns of the tagged dolphins relative to normal dolphins. However, evaluations can still be performed even without an ideal follow-up monitoring dataset and reference information, with the use of appropriate caveats ad qualifications regarding limits of available information.

A summary of the tracking data as they relate to evaluation of the status of the dolphins at the time of final post-release monitoring contact is presented in Table 11. The status is compared to the working definition of success presented above, available information about the biology of the species, and tag performance specifications provided by the manufacturers.

Information on the status of the five dolphins tagged only with VHF transmitters is limited, as they were only within range of tracking while they were in the shallows west of Andros Island. They were observed from a helicopter at this time, four days post-release. The group with which they were released was still intact at this time. Except for the fact that the entire group was out-of-habitat in very shallow water, no problems were evident from aerial photos (Figures 6a, 6b). However, it should be noted that the information that can be reasonably gleaned from such photos is minimal. As no data are available for these five animals after 7 May, the only conclusions that can be drawn from follow-up monitoring is that they survived their first four days post-release. All subsequent discussion will focus on evaluating the five dolphins that received satellite-linked tags.

Table 11. Summary of tracking data as they relate to evaluation of dolphin or tag status at the time of final contact with the animal. "+" indicates that the animal met or surpassed "normal" or expected values or patterns. "-" indicates less favorable findings. "na" indicates that it was not possible to measure a parameter. "?" indicates that under the correct circumstances the parameter could have been measured, but the situation did not allow measurement, or the findings were unclear, so the status of the animal or tag relative to this parameter remains unknown.

Parameter	SbRtY366 Notch 39381	SbRT R307 54612	SbRT Y352 57604	SbRTR 136	SbRT R304	SbRT R306	SbRT R354	SbRT Y354/ Y372	SbRT R134 42480	SbRT R372 42481
Contact Duration ≥ 28 days	+	+	+	-	-	-	-	-	-	-
Status at Time of Final Contact (relative to expected normal values):										
Habitat	-	+	+	-	-	-	-	-	+	+
Travel Rates	-	-	+	na	na	na	na	na	-	-
Max. Dive Depths	na	+	-	na	na	na	na	na	+	+
Dive Durations	na	+	?	na	na	na	na	na	+	-
Social Associations	na	?	+	+	+	+	+	+	+	?
Tag Battery > 3 volts	+	+	+	na	na	na	na	na	+	-
# Transmissions ≥ Est.Total	+	-	-	?	?	?	?	?	-	-

Contact Durations

Three of the five dolphins (Notch, SbRTY352, and SbRTR307) exceeded the 28-day tracking duration criterion. The two dolphins released in September, SbRTR134 and SbRTR372, were tracked for only 12-14 days. When tracking does not last as long as anticipated, the logical questions that arise are whether loss of contact was due to failure of the animal or equipment, or some other factor. Each of these possibilities is considered below.

Habitat and Ranging Patterns

Most of the data from tracking support the idea that stenos are primarily deep-water dolphins (Leatherwood and Reeves 1983; Miyazaki and Perrin 1994). Two rehabilitated stenos released in the Gulf of Mexico in 1998 remained in waters of depths averaging about 195 m, typically over or near an escarpment (Wells *et al*. 1999). Three rehabilitated stenos released from near Ft. Pierce, Florida in March 2005 moved through waters averaging more than 1,100 m (Wells and Gannon 2005). Dolphins in the Canary Islands were observed in waters ranging from 20 m to 2,500 m, averaging about 506 m (Ritter 2002). Rough-toothed dolphins off Brazil were observed feeding in waters of 5 m to 39 m depth (Lodi and Hetzel 1999). Hawaiian stenos are typically found in waters more than 1,500 m deep (R.W. Baird, pers. comm.). Four of the five tagged dolphins spent most of their time in waters consistent with depths previously reported for stenos, averaging more than 300 m, and often exceeding several thousand meters. In light of subsequent movements and available literature, the milling and slow movements of the May dolphins for several days over the very shallow waters west of Andros Island should be considered highly anomalous, and likely an indication of disorientation following release. Notch was an exception to the general patterns of the other four, spending most of his time over the

continental shelf in waters averaging about 122 m deep, and averaging only 2 m in depth during the last three days of his track. On occasion, several of the tagged dolphins were tracked near or along steep escarpments, but this was not the case for the majority of position records.
As more data are collected, new information expands the known temperature range for the species. Leatherwood and Reeves (1983, page 182) state: "When live, free-ranging rough-toothed dolphins have been reported, associated sea surface temperatures have always been above 25^{o} C." Three rehabilitated stenos released by Mote Marine Laboratory and Gulfarium in the Gulf of Mexico in 1998 exhibited an apparent preference for waters of 25^{o} C on average (Wells et al. 1999). However, off the Canary Islands, rough-toothed dolphins were observed throughout the year in waters that ranged from 17^{o} to 24^{o} C (Ritter 2002). Rough-toothed dolphins off Brazil were observed feeding in waters of 22^{o} to 24^{o} C (Lodi and Hetzel 1999). Three stenos released off Ft. Pierce, Florida in 2005 moved from waters averaging 24^{o} C during the first week of their track into waters of 19^{o} C for the remainder of their track (Wells and Gannon 2005). The tagged stenos moved through waters ranging in temperature from 17^{o} to 31^{o} C, averaging 21^{o} to 30^{o} C. This extends the upper range of water temperatures documented for this species.

Rough-toothed dolphin ranging patterns are not well known for many parts of the world. They have been studied at several sites where they have demonstrated strong site fidelity to deep waters near oceanic islands, such as the Canary Islands and Hawaii (Ritter 2002; R.W. Baird, pers. comm.). Released rehabilitated stenos have typically moved long distances, sometimes to areas where the movements become cyclical or limited to a specific region. Two stenos released in 1998 off Sarasota, Florida traveled through the Gulf of Mexico to a deepwater region in the northeastern Gulf directly offshore of their stranding site. One dolphin was tracked moving back and forth through an area extending NW to SE about 280 km, for 112 days, and both were identified, with other dolphins, in this area 157 days post-release (Wells et al. 1999). A third steno from the same mass stranding released by Gulfarium during this track moved through the same area, but did not appear to join the Mote dolphin. Rehabilitated stenos released from near Ft. Pierce in March 2005 moved northeast to a deepwater area off the NC-VA border, where they then made a large circle through the remainder of the track (Wells and Gannon 2005).

All three of the releases from the same original mass stranding event described in this report yielded very different tracks. Notch completed a large circle that took him from Florida to South Carolina and back, with at least the second half of the track involving habitat not commonly used by stenos. The stenos released in May initially paused in inappropriate habitat off the Bahamas before continuing on a long track through deep water, roughly paralleling the Greater Antilles and the Leeward Islands. The September dolphins moved to the north shore of Cuba, where they milled for several days in an area where a trench is very near to shore. While Notch does not appear to have had a ranging pattern consistent with others reported for stenos, it can be argued that the other two releases were not inconsistent with expected steno patterns.

Travel Rates

Average rates of travel exhibited by the tagged dolphins were consistent with published reports. Wells and Gannon (2005) reported average values of about 3.3 to 4.6 km/hr for released rehabilitated stenos in the Atlantic, and Ritter (2002) reported values of 3.7 to 5.6 km/hr for traveling rough-toothed dolphins in the Canary Islands. The tagged stenos moved at average rates of 3.9 to 5.7 km/hr. However, four of the five tagged dolphins exhibited declines in their travel rates to about 2 km/hr toward the end of the tracking periods. These declines are of concern, but in the absence of other information they are difficult to interpret.

Dive Depths

Dive depths exhibited by the four tagged dolphins equipped with dive measuring instrumentation were mostly consistent with the few available reports of rough-toothed dolphin dive depths. Only a few dives were to depths in excess of 50 m, and dives to 100 m to 300 m were very rare and only performed by half of the tagged dolphins. Norris *et al*. (1965) trained a rough-toothed dolphin to dive repeatedly to depths of 30 m. Watkins *et al*. (1987) reported free-ranging rough-tooth dolphins echo-locating and rubbing on a hydrophone at a depth of 70 m. Most dives by the three rehabilitated stenos released from near Ft. Pierce were to less than 30 m (Wells and Gannon 2005). Several reports from other sites indicate that rough-toothed dolphins engage in a variety of activities, including feeding, at or near the surface (Lodi and Hetzel 1999, Ritter 2002). Evidence in support of feeding near the surface comes from stomach content data, observations of feeding on mahi mahi, and observations of regular feeding on near-surface prey such as flying fish, needlefish and unidentified small schooling fish (Miyazaki and Perrin 1994; Pitman and Stinchcomb 2002; R.W. Baird pers. comm.).

The tagged dolphins rarely dove to the sea floor, but instead mainly worked the top 50 m or so of the water column. Only one dolphin, SbRTY352, exhibited a pattern of decline in maximum daily dive depth in the absence of a dramatic change in water depth. It is possible that this could indicate a health problem, especially since it was associated with changes in dive duration patterns (see below), but this can not be considered conclusive.

Dive Durations

The results from the tracking of the four dolphins with tags that provided dive information do not support early descriptions of rough-toothed dolphins as "primarily a diving species," making occasional dives of 15 minutes duration (Norris *et al.* 1965, Miyazaki and Perrin 1994), but they were consistent with several recent reports for free-ranging rough-toothed dolphins. Dives of more than 3 min by the three stenos released from near Ft. Pierce were rare (Wells and Gannon 2005). Ritter (2002) noted that Canary Island rough-toothed dolphins made repeated dives of 0.5 min to 3.5 min, and Lodi and Hetzel (1999) described repeated feeding dives of 1.5 min. Ritter (2002, pg. 51) described a "sneaking" behavior in which rough-toothed dolphins "moved smoothly and non-energetically, surfaced without splashing, and stayed submerged , but close to the surface (only the tip of the dorsal fin emerged), while swimming, and changing direction frequently," making the dolphins difficult to resight. Given the lack of subsequent reports of 15 min dives since the early accounts, perhaps these extraordinarily long dives could be explained as artifacts of sneaking behavior, leading to over-estimates of dive durations in some cases when such estimates were made visually in the field.

Few dives by any of the four tagged dolphins exceeded 4 min. For the purposes of evaluating the status of the animals, increases in the proportion of brief dives and declines in the proportions of long dives over time were considered to be of concern. SbRTY352 showed a trend towards the end of the track involving an increased proportion of the briefest dives, but the animal still performed dives in excess of 180 sec even during the final tracking period. Of greater potential concern was the finding that SbRTR372 exhibited a dramatic increase in the proportion of the briefest dives, with a concomitant decrease in deep and intermediate-length dives, during the final tracking period.

Social Patterns

The apparently continuous long-term associations between the two pairs of tagged dolphins were consistent with published reports about the complex social behavior of this species. When available, location, dive, and travel rate data supported the idea that the pairs of similarly-tagged animals within each release group remained together, at least until transmissions ceased for one member of each pair. In addition, the seven members of the May release group remained together for at least the first four days following release. It is not known if Notch or Naia ever encountered or joined other stenos. Even though they stranded together, there is no indication that the three different release groups reunited, and observed movement patterns taking the groups in very different directions make such reunions unlikely.

In addition to the fact that mass strandings of this species are not infrequent, observations during previous steno rehabilitations and post-release tracking results reinforce the idea that the social bonds between members of this species can be strong. The two rehabilitated stenos released by Mote Marine Laboratory into the Gulf of Mexico in 1998 were observed together 157 days post-release (Wells et al. 1999). The three stenos released from near Ft. Pierce in 2005 exhibited frequent and intensive social interactions during rehabilitation, including food sharing, supportive or epimeletic behavior, and whistle exchanges, and they appeared to remain together through the tracking period for which data from multiple tags were available (Wells and Gannon 2005). Ritter (2002, pg. 50) reported: "An outstanding behavioural peculiarity of this species was the formation of tight subgroups, which behave extremely synchronously." There are numerous reports in the literature of complex social interactions, including coordinated feeding patterns, food-sharing, and epimeletic behavior (Lodi 1992, Miyazaki and Perrin 1994, Lodi and Hetzel 1999).

Tags and Attachments

None of the five satellite-linked tags achieved its full potential relative to projected battery life. Only one (Notch) reached or exceeded the expected number of transmissions. Battery strength at last transmission for four of the five tags, including Notch, indicated adequate levels for continued transmissions ($\geq$ 3.00 volts). The fifth tag was only slightly below this nominal battery voltage value; in our experience other tags have continued to transmit successfully at values well below the 2.92 volts registered for SbRTR372. Current draw remained normal for the four (Splash) tags for which these data were provided. Thus, neither battery exhaustion nor failure of electronics was clearly indicated as the primary cause of transmission cessation for any of the tags. Possible alternatives include: 1) tag attachment failure, or 2) death of the dolphin.

Tag loss due to active removal or failure of attachments is a strong possibility. Including the tagging reported here, Mote Marine Laboratory's Center for Marine Mammal and Sea Turtle Research has used a similar three-pin, side-mount attachment technique for satellite-linked transmitters on rough-toothed dolphins nine times to date. Signals were received for periods of three to 112 days, averaging 28 days. It is not possible to specifically identify tag shedding or attachment failure as the cause of loss of contact in any of these cases, but in each case tag electronics indicated acceptable levels of performance prior to loss of contact. In the only case where follow-up observations were possible, both tagged Gulf of Mexico dolphins were seen 157 days after release (45 days following cessation of transmissions by one tag), having successfully shed their tags, without injury (Wells *et al*. 1999).

The possibility that at least some of the tags were removed from the fins by other stenos must be considered. The stenos released near Ft. Pierce in 2005 engaged in allogrooming during their lengthy rehabilitation at Mote Marine Laboratory (Wells and Gannon 2005). This allogrooming took the form of removing roto-tags attached to dorsal fins. Five of six rehabilitating rough-toothed dolphins lost their roto-tags during the first three to four weeks of rehabilitation, presumably from being pulled off by other dolphins. One dolphin was observed on at least three occasions mouthing and chewing the roto-tags of the other animals. This animal was the last to lose its own roto-tag in the rehabilitation pool, but the first to cease satellite-linked transmissions.

As discussed at the "Small Cetacean Electronic Tag Attachment Workshop" in 2003, tag attachment configurations exist that can provide tracking opportunities over periods of a year or more, but with these longer, larger, stronger attachments come increased risks of injury to the animal from the tag itself (Wells 2005). Selection of tag and attachment designs involve trade-offs; no invasive tag is without some level of risk. In cetacean rehabilitation, increased risks of injury to the animals from the tag itself, working counter to the rehabilitation efforts, may not be offset by the value of the information to be gained from longer tracking. If, for example, a tag becomes entangled in line or a net, then it should be able to shed easily without compromising the animal. The three-pin side-mount design was selected in these nine cases specifically because it was believed to minimize risks to the animals, though at a potential cost to duration of tracking. The average tracking duration of 28 days for the nine tags matches the working criterion for desired minimum tracking duration for identifying successful rehabilitation efforts.

Overall Assessment of Success

In the absence of strong, direct evidence to the contrary, these three releases of ten tagged stenos should be considered as qualified successes. Three of the dolphins were documented as having survived more than four weeks, exceeding a working criterion for success. In spite of the fact that the final contacts with eight of the 10 dolphins were near shore, no carcasses were reported or recovered. Because none of the animals was found to be acceptable in all categories considered for evaluation of success (Table 11) and seven dolphins were not tracked for a minimum of 28 days, consideration of the releases as successes must be made with caution. None of the sub-standard performance measures, considered individually or in combination, seemed to be of sufficiently serious concern to lead to a strong conclusion that an animal had died, but mortality in the absence of carcasses remains a possibility. Off the north shore of Cuba, off the west coast of Andros Island, or in the open ocean northeast of the Leeward Islands, carcass recovery would not be likely. However, abrupt loss of radio contact with each of the dolphins with satellite-linked transmitters, in the absence of marked behavioral changes, suggested either a catastrophic biological event such as predation or, more likely, failure of the tag or especially the attachment system.

Without subsequent observations of the animals it is difficult to distinguish between tag and attachment failure. Status reports transmitted by the tags indicated that most performance parameters were within normal ranges prior to cessation of transmission, but this does not necessarily rule out the possibility of catastrophic failure of the tags' electronics. However, tag attachment failure, possibly through the actions of another dolphin, may be the more likely scenario. This hypothesis is supported by the tag removal behavior documented for stenos during rehabilitation, as described above.

Recommendations

The results of this project support the idea that every effort should be made to release animals from mass strandings together. Rough-toothed dolphins are highly social animals, with strong inter-individual bonds and complex interactions. It seems clear from the tracking data that releasing members of the stranded school in three separate instances disrupted whatever school integrity might have remained at the time of stranding, beyond the changes from the deaths of school members. The May animals clearly demonstrated disorientation shortly after release. While they may have survived the stranding and the rehabilitation process, the lives of the animals in decimated subgroups was likely very different from what they had experienced prior to stranding, and long-term survival and school functionality can not be assumed. Given the demonstrated and hypothesized functions of dolphin schools (Norris and Dohl 1980), it is reasonable to ask if it would have been in the animals' better interests to release as many of them as possible together. Notch and Naia were released just two weeks before the release of nine others off the Florida Keys. In retrospect, perhaps it would have been better to retain them for release with others from their school. This approach was considered, but at the time of release of the MARS animals there was no firm schedule for releasing the MMC dolphins, and there were concerns regarding adverse impacts on the health of the MARS animals from retaining them for too long beyond the time when their rehabilitation and medical clearance were complete.

Dolphins should be released near their original stranding site, or nearest appropriate habitat to that site, whenever possible, in order to try to minimize potential disorientation upon release. Notch and Naia were released in presumed steno habitat well north of the stranding site, and Notch demonstrated the most inappropriate movement patterns of any of the released stenos.

The movements of the stenos both offshore and nearshore pointed to the value of double tagging the animals for both remote and real-time direct tracking. VHF transmitters facilitated locating and observing the May stenos in the shallows near Andros Island. If Notch or Naia had been equipped with a VHF transmitter, then it might have been possible to observe them during Notch's repeated and extended periods of movement near the eastern coast of the United States.

Remote tracking with satellite-linked transmitters provides an important tool for monitoring pelagic cetaceans post-release. For the purposes of evaluating the success of a rehabilitation effort, an average tracking duration of 28 days is minimally acceptable, given that some veterinarians consider four weeks without indications of problems to be a minimum criterion for claiming success. Longer tracks, at least through the projected battery life of 70^+ days, would be desirable. Assuming that tag electronics are currently not a limiting factor, then efforts should be directed toward developing smaller tags and safer, more effective, and longer tag attachments. Discussions are underway with tag manufacturers and elsewhere to bring about improvements.

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